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WATER RESOURCES CONFERENCE WORKBOOK

Public Health Service
Dallas, Texas

May 1961

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FOREWORD

This is a collection of papers to be given at the first Public Health Service Water Resources Conference. They are being sent to you in order that you may have an opportunity to read and study them prior to the meeting and thus be better able to enter into their discussion. By so participating, you will contribute to the development of policies and procedures that we hope will ultimately be those of the Public Health Service, and you will assist in making this conference a success.

YOUNG

PUBLIC HEALTH SERVICE

WATER RESOURCES CONFERENCE

May 24, 25, and 26, 1961

Dallas Hotel — Dallas, Texas

May 24, 1961

9:00 - 9:05 a.m.	Opening Remarks Jerome H. Svore
9:05 - 9:15 a.m.	Welcome E. C. Warkentin

First Session

Moderator - Robert W. Haywood, Jr.

9:15 - 9:45 a.m.	Water Resources Planning - Positive versus Negative Approach Keith S. Krause
9:45 - 10:15 a.m.	Discussion - Leader: Lester M. Klashman
10:15 - 10:30 a.m.	Coffee Break
10:30 - 11:00 a.m.	Population Forecasting - Methodologies and Merits William E. Torget
11:00 - 11:30 a.m.	Discussion - Leader: Richard S. Green
11:30 - 11:45 a.m.	Conclusions

Second Session

Moderator - Paul W. Eastman, Jr.

1:15 - 1:45 p.m.	Growth Factors in Economic Base Studies John H. Davidson
1:45 - 2:15 p.m.	Discussion - Leader: James J. Flannery
2:15 - 2:30 p.m.	Conclusions
2:30 - 2:45 p.m.	Coffee Break
2:45 - 3:15 p.m.	Location Factors Charles H. Hajinian
3:15 - 4:00 p.m.	Discussion - Leader: David A. Robertson
4:00 - 4:15 p.m.	Conclusions
6:~~30~~00 - 7:30 p.m.	Dinner - Speaker: Dr. Richard F. Boyd

May 25, 1961

Third Session

Moderator - H. W. Poston THOMAN

9:15 - 9:45 a.m.	Projecting Water Requirements in the Boondocks Walter R. Hager
9:45 - 10:30 a.m.	Discussion - Leader: Francis A. Jacocks
10:30 - 10:45 a.m.	Conclusions
10:45 - 11:00 a.m.	Coffee Break
11:00 - 11:30 a.m.	Agriculture - Effects on Water Demands Willis G. Eichberger
11:30 - 12:00 noon	Discussion - Leader: Garry L. Fisk
12:00 - 12:15 p.m.	Conclusions

Fourth Session

Moderator - Kaarlo W. Nasi

1:30 - 2:00 p.m.	Estimating Future Water Demand Charles R. Ownbey
2:00 - 2:30 p.m.	Discussion - Leader: Paul DeFalco, Jr.
2:30 - 2:45 p.m.	Conclusions
2:45 - 3:00 p.m.	Coffee Break
3:00 - 3:30 p.m.	Must Water Treatment Be High Priced? Earnest F. Gloyna
3:30 - 4:00 p.m.	Discussion - Leader: Herbert C. Clare
4:00 - 4:15 p.m.	Conclusions

May 26, 1961

Fifth Session

Moderator - John R. Thoman

8:30 - 9:00 a.m.	Must Stream Quality Be Maintained? F. W. Kittrell
9:00 - 9:30 a.m.	Discussion - Leader: W. W. Towne
9:30 - 9:45 a.m.	Conclusions

May 26, 1961

9:45 - 10:00 a.m.	Coffee Break
10:00 - 10:30 a.m.	Principles and Policies for the Evaluation and Reimbursement of Water Supply and Pollution Abatement Benefits from Federal Storage Projects M. E. Scheidt
10:30 - 11:00 a.m.	Discussion - Leader: Lloyd W. Gebhardt
11:00 - 11:15 a.m.	Conclusions
11:15 - 11:45 a.m.	Should the Public Health Service Take a Stand and Make Secondary Treatment Mandatory? William H. Davis
11:45 - 12:15 p.m.	Discussion - Leader: John F. Smouse
12:15 - 12:30 p.m.	Conclusions
12:45 p.m.	Luncheon

Sixth Session

Moderator - Jerome H. Svore

1:30 p.m.	A Review of Conclusions and Agreements for Future Action Leonard B. Dworsky

①

NOTES

WATER RESOURCES PLANNING - KEITH S. KRAUSE -

WATER QUALITY CONTROL IS THE MAJOR FACTOR

IN WATER MANAGEMENT.

Fed WR development 1st 1822 CANAL IMPROVING TRANSPORTATION -

20 yr proir to C.W. 1840 ± FLOOD CONTROL

MISS COMMISSION - 1875 1st FLOOD CONTROL STUDY.

1880 - CONSERVATION OF NATURAL RESOURCES

HYDRO AND IRRIGATION - PUBLIC HYDRO ELEC POWER

1928 Fed Power Comm -

NORRIS AND TVA 1933 - WATER FOR RECREATION - PH INDUSTRY. ETC.

1935 Conference on Water Resources 1944 bill almost passed.

1948 WPC. 1958 Water supply act.

QUANTITY - QUALITY QUALITY NOT Recognized at first

NATION IS BECOMING AWARE TO IMPORTANCE OF QUALITY.

LES KIASHMAN (GET COPY OF DWORSKY'S PAPER)

20 STATES WITH SEPARATE W.R. COMMISSIONS ✓

WHAT IS MUST BE THE P.H.S. RELATIONSHIP WITH THIS NEW AGENCIES

QUESTION: WHY ISN'T DILUTION A SUBSITUTE FOR TREATMENT?

keith.

NEEDS TO BE DISCUSSED but after Mel Scheidt Paper -

RIVER BASIN PLANNING NO ONE BEST WAY. - (Senator Kerr)

FLANNERY. 20 STATE AGENCIES - PHS deals with water Quality

has a most important role. must prevail.

SMA
STANDARD METROPOL AREAS

POPULATION FORECASTING - METHODOLOGIES AND MERITS

William E. Torget
Water Resources Section
Division of Water Supply and Pollution Control
Public Health Service, Region VII
U. S. Department of Health, Education, & Welfare

Introduction

One of our primary tasks is to forecast the water demand for a designated area half a century hence. The water demand is a function of the number of people and the activities of these people. We will concern ourselves here with the number of people. We will further limit our concern to the forecast of population for the larger cities. This limitation, however, obviously necessitates a forecast of the country and other major subdivisions.

The task before us is to determine what will be the probable population in a given metropolitan area 50 years from now. Having estimated that, then what is the probable error of this estimate? The agency that does most of the forecasting - Bureau of the Census - has this to say about its own forecasts: "It should be borne in mind that the projections to 1980 are all quite speculative; and that the projections for the year 2000 are of the nature of a mathematical exercise." And we are required to go a decade or two beyond a point that is already 20 years removed from a time that only a very speculative forecast can be made. It is little wonder why so many souls become timid and attempt to shield themselves with a phrase such as, "These are projections and not predictions," or else to predict such a wide range of growth possibilities that the forecast cannot miss if the city has a population explosion or a hydrogen explosion.

We have no such escape clause. We must come up with an extrapolation, a projection, or a forecast (A forecast by any other name is still a forecast and let's call it such). Let's grant, without apology, that the likelihood of forecasting with precision is astronomically small. Since we grant that an error in forecasting will be made, then what data and knowledge can we use to minimize the error? Perhaps the best indicators will be past trends; especially, if they have been relatively consistent. Past trends may or may not prevail, but if the last 50 years indicate a stable trend, this may be our best source for predicting the next 50 years. What else do we have? To assume a radical departure would seem less tenable.

What trends do we need to investigate? Because we are here to get answers we must be pragmatic and not pedantic, so we will limit ourselves to examining those trends that may have predictive ability.

The questions considered will be:

What has been the rate of growth of the total SMA population and what will it be in the future?

Do SMA's of varying size groups grow at different rates?

Is there a wide dispersion in growth rates among SMA's in the same size group?

Do SMA's tend to have a relatively stable rate of growth?

Is the rate of growth of SMA's correlated with the area in which it lies?

Given the answers to the questions above, what growth patterns can be forecast?

What other methods of forecasting are used?

What has the growth rate been for the total SMA population and what will it be in the future?

Growth of the metropolitan population has been one of the most conspicuous features of the population movement of the United States during the first half of the 20th century. For all decades the SMA population has grown at a more rapid rate than that of the Nation.

Table 1

Percentage Increase in SMA*, and
Total National Population
for the decades 1910-1960

Decade	SMA*	Total National Population
1910-20	33.8	14.9
1920-30	32.1	16.2
1930-40	9.3	7.2
1940-50	26.0	14.3
1950-60	29.6	18.9

* The SMA population for all decades is that residing in the geographic area that was defined as SMA in 1960.

It is observed that the SMA population increase has been relatively constant for the last 5 decades (ranging from 26-33 per cent) with the exception of the depression decade. The out-of-trend population increase in the SMA population during the 1930's, was the result of a low national increase and a restricted rural to urban migration. The differential growth rate of the SMA and Non-SMA is primarily explained by the marked migration into the SMA's.

The growth trend of the total SMA population indicated in Table 1, however, cannot be used to depict the average growth trend of the SMA's because the base is changing; i.e., more cities are included in the end of the decade than in the beginning of the decade. When the data is standardized to exclude the population of those SMA's that were added during the decade, the growth rate is more uniform. Again, with the exception of the depression years, the average SMA growth varied between a narrow range -- from 21 to 26 per cent.

Table 2

Percentage Increase in SMA*, and
Total National Population
for the Decades 1910-1960

	Percentage Increase for Decade		
Decade	SMA-2	Non-SMA's	National Total
1910-20	24.4	9.0	14.9
1920-30	26.6	8.0	16.2
1930-40	8.1	6.4	7.2
1940-50	21.4	6.3	14.3
1950-60	24.5	11.3	18.9

*The SMA population for all decades is that which resided in the geographic area defined as SMA in 1960. It includes, however, only the increase in the SMA's that meet the requirements for SMA in the beginning of each decade. Hereafter this will be referred to as SMA-2. Those cities that met the SMA criterion only at the end of each decade is included in the Non-SMA population.

The apparent consistency of the SMA-2 population increase during these 4 decades is an illusion and cannot be used in prediction. First, the national population increase varied and the relative size of the source of migration (the Non-SMA population) varied. If the effect of these two factors are standardized by the conditions which prevailed during the 1950-60 decade, the growth of the SMA-2 population would show a declining trend.

Table 3

Standardized SMA-2 Population Increase
by Decades 1910-1960

Decade	Percentage Increase
1910-20	33.1
1920-30	29.4
1930-40	27.0
1940-50	26.3
1950-60	24.5

This decline in the rate of increase for the SMA-2 population perforce must continue for the obvious reason that the relative size of the Non-SMA is decreasing and hence one of the main sources of growth, i.e., migration from the Non-SMA, is becoming relatively smaller and will, therefore, contribute relatively less to the SMA-2 growth. Table 4 demonstrates this.

Table 4

Trend in the Ratio of Non-SMA Population to SMA-2 Population by Decades 1910-1960

Decade	SMA Population (in millions) at Beginning of Decade	Non-SMA Population (in millions) at Beginning of Decade	Ratio of the (migration pool) Non-SMA to SMA Population
1910-20	35.3	56.7	1.61
1920-30	47.2	58.5	1.24
1930-40	62.3	60.5	.97
1940-50	68.1	63.6	.93
1950-60	85.8	64.9	.76

Given these past 50-year trends, (1) what will be the forecast in the total SMA population, and (2) what will be the forecast increase in the growth of the SMA-2 population? (A national population of 380,000,000 in 2010 will be assumed. Justification for the adoption of this figure will be stated later.) The total SMA population, which increased 215 per cent during the last 50 years, will increase 157 per cent to 300,000,000 the next 50 years. The decrease in the rate of increase will happen in spite of the fact that the national population is assumed to increase a little more rapidly in the next 50 years than it did in the previous 50 years. The explanation is that one of its primary sources of population, the Non-SMA pool, is becoming relatively smaller. The SMA-2 population will witness a decline in the rate of increase from 24 per cent in 1950-60 to 17.8 per cent between 2000-10. To assume that the present rate of SMA population increase will continue, as many mistakenly do, is tantamount to assuming a national population of approximately 500,000,000. Few predict a forecast this high. These forecasts are based on projections shown on Figure 1. Note the fairly consistent growth trends of the past 50 years for both the SMA and Non-SMA population.

Table 5

Trends and Forecast of SMA Population
by Decades 1910-2010
(Population in millions)

Year	Number of SMAs	Total SMA[1] Population	Per Cent Increase	Total Adjusted SMA[2] Population	Per Cent Increase[3]
1910	91	35.3			
			33.8		24.4
1920	119	47.2		43.9	
			32.1		26.3
1930	144	62.3		59.6	
			9.3		8.1
1940	151	68.1		67.3	
			26.0		21.4
1950	176	85.8		82.7	
			29.6		24.5
1960	210	111.2		106.8	
2000		250.2		246.0	
			19.8		17.8
2010		300.0		295.0	

1/ Total SMA population the decade indicated.

2/ SMA population of those SMA's which qualified as SMA's the preceding decade.

3/ The 24.4 per cent, for example, is derived from 43.9 ÷ 35.3.

POPULATION TRENDS and FORECASTS for S.M.A., NON-S.M.A., and TOTAL U.S. POPULATION 1910 — 2010

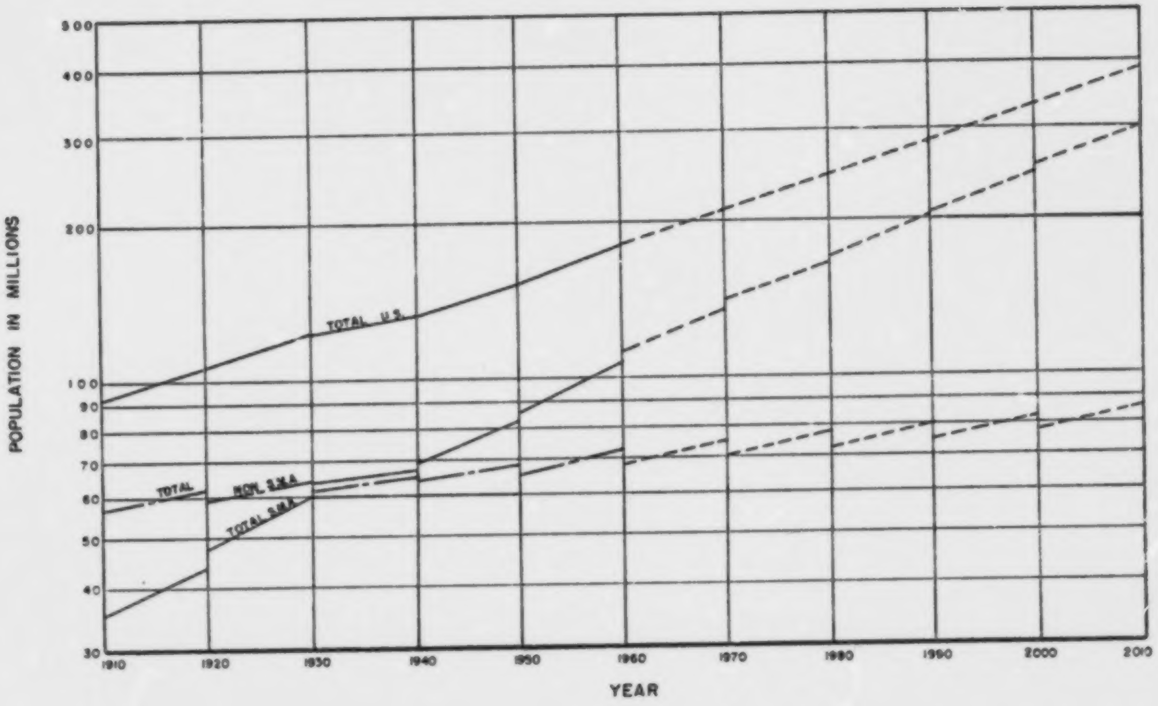

FIGURE 1

The foregone analysis is not intended to be used to forecast an individual SMA; it is only to establish a ceiling for the rate of increase of the SMA's, and furthermore, to remind us that the rate of increase of SMA's must decrease if we assume any national population forecast short of approximately 500,000,000.

Before turning our attention to the individual metropolitan area, let's see if there are significant differential growth rates among various size SMA's. Do smaller ones grow more rapidly than larger ones? Do these cities slow down as they get larger?

Is the rate of growth associated with size? An answer to this question can be approximated two ways. First, we can group cities into several size categories and see if the smaller ones grow at a different rate than the larger ones. This has obvious shortcomings because the only factor being held constant is size, and size is not the major determinant in the rate of growth. Because many use this technique, it is well to examine these trends. A better measure, because it would have greater predictive value, would be to determine if the individual cities vary in rate of growth as they get larger. This, too, is difficult to ascertain because the growth potential varies between decades. For example, in the 1930 decade, the population of the country grew at less than half the rate of any of the other decades studied; whereas, the recent decade witnessed the greatest absolute, as well as relative, growth. This obviously affects and is affected by the growth rate of SMA's. An examination of the question is nevertheless worthwhile because it may lead us to "ball park" figures. If not, it is equally important to expose erroneous forecast methods.

The median growth rate is remarkably constant for the cities in the 4-size classes, between 100 thousand and 1.6 million. The average for the 5 decades ranged from 17.2 per cent to 19.6 per cent. There was greater variability, however, within a size class from one decade to another. Nevertheless, the range was not large. The cities under 100,000 and those over 1,600,000 grew at a slower rate. The reason for the lower rate of increase for the smallest group is that a disproportionately large part of their metropolitan area is rural. If the effect of this were eliminated, cities under 100,000 would grow at approximately 19 per cent also. This data suggests that size, within the limits mentioned, does not affect the rate of growth. The statement is equally true of individual cities. Cities between 100,000 and 800,000 do not decrease in the rate of growth as they get larger. The growth rate must be decreased for reasons mentioned earlier (the relative migration from Non-SMA's is decreasing) but not because the city is growing from, for example, 300,000 to 800,000.

Table 6

Population Increases in SMA's of Varying Size-Classes 1910-1960

	Under 100,000	100-200,000	200-400,000	400-800,000	800-1,600,000	Over 1,600,000	Total SMA Population
Number	15	32	23	15	2	4	91
1910	1,279,866	4,540,290	6,302,265	8,780,979	2,503,536	11,849,576	35,256,512
1920	1,528,089	5,901,813	7,693,545	11,601,712	2,926,421	14,224,524	43,876,104
Mean	19.4	30.0	22.1	32.1	16.9	20.0	24.4
Median	22.4	23.4	21.2	23.8	16.4	19.0	
Number	16	47	32	12	7	5	119
1920	1,351,379	6,603,106	9,122,690	6,819,983	7,288,751	15,984,513	47,170,422
1930	1,633,518	8,223,378	10,942,650	8,268,542	10,768,405	19,753,621	59,590,114
Mean	20.9	24.5	19.9	21.2	47.7	23.6	26.3
Median	15.3	18.2	18.3	20.6	33.5	16.0	
Number	23	51	37	19	7	7	144
1930	1,970,013	7,276,853	10,280,272	10,445,550	8,057,899	24,258,130	62,288,717
1940	2,117,498	8,125,941	11,163,637	11,262,716	8,549,984	26,095,463	67,315,239
Mean	7.5	11.7	8.6	7.8	6.1	7.6	8.1
Median	5.2	9.5	7.2	6.6	5.6	3.4	
Number	20	54	42	19	9	7	151
1940	1,708,770	7,775,723	11,736,553	10,436,693	10,350,174	26,095,463	68,103,376
1950	2,110,688	9,866,820	14,610,423	12,748,706	12,960,743	30,412,775	82,710,155
Mean	23.5	26.9	24.5	22.2	25.2	16.5	21.4
Median	16.8	22.4	19.8	21.5	17.4	13.3	
Number	18	62	47	28	12	9	176
1950	1,467,122	8,800,958	12,982,471	14,966,685	13,246,952	34,372,830	85,837,018
1960	1,748,442	11,163,348	16,271,351	19,715,530	16,726,103	41,218,740	106,842,514
Mean	19.2	26.8	25.3	31.7	26.3	19.9	24.5
Median	17.7	24.4	19.3	25.4	25.4	19.0	
Number						(new) 34	210
1960						4,406,190	111,248,704
Mean of above medians							
Excluding '30's	18.1	22.1	19.6	22.8	23.2	16.8	
Including '30's	15.5	19.6	17.2	19.6	19.6	14.1	

Knowledge of the average growth rate and the correlation of size and growth rate is useful but one cannot rest his forecasts on these. There are wide deviations from these averages. While it is true that one will miss the forecast on the total population of a group of cities less if he uses the average, there are measures more accurate for individual cities. Let's next examine the extent of the variation from the average.

Is there a wide dispersion in growth rates among SMA's? There is an extreme range in the rate of change. Some more than double during a ten year span, while others experience decreases. The smaller SMA's have a greater disparity in the rate of growth than larger cities. Even the size group that had the least variability in the rate of growth during the 1950-60 decade -- the 800,000 to 1,600,000 class-- varied from a low of 15 per cent increase to a high of 53 per cent. The difference in these rates is greater than is first apparent. If one were to project an SMA of 1,000,000 population on the bases of these two rates compounded every decade; he would show a projection of 1,600,000 and 8,000,000. And remember the other size groups vary more. See Table 7.

This is not to say, however, that no discernible pattern exists. Remember, these are the extreme variations in the rate of growth and there are obviously few SMA's at either the upper or lower end of the scale. To show the variation between these extremes and to bring order to this mass of data, the rate of growth is tabulated for SMA's by size groups and by relative rank in Table 7 for four previous decades. To show this dispersion, the percentile rank was computed. The 75th percentile, for example, indicates the percentage growth that above which 25 per cent and below which 75 per cent of the SMA's experienced. The percentile growth rates for each SMA size group were averaged for all decades to more nearly approximate the rate of growth over time. The 1930-40 decade was eliminated because it was atypical, while the other four decades had a relatively uniform national growth rate and one which coincides with the projected national growth rate. Variability in the growth rate between decades within the same percentile rank of a given SMA size class exists, but is not great in the 25 to 75 percentile rank. For example, the SMA (size class 200,000 to 400,000) in the 75th percentile growth rank increased between 28 per cent and 31 per cent for an average of 30 per cent. The median or 50th percentile increased from 18 to 21 per cent, or an average of 20 per cent, while the 25th percentile increased between 11 per cent to 18 per cent for an average of 14 per cent. Figure 2 shows the average of these percentile growth rates. Note the uniformity of the rates of growth for the 75th to 25th percentile rank for the cities between 100,000 to 1,600,000. As mentioned previously, the SMA's under 100,000 are expected to more closely approximate the rate of increase of the other SMA size groups in the near future. It is only the SMA's over 1,600,000 that deviate from this pattern.

RANGE IN PERCENTAGE GROWTH OF SMA'S OF VARYING SIZE GROUPS 1910-1960

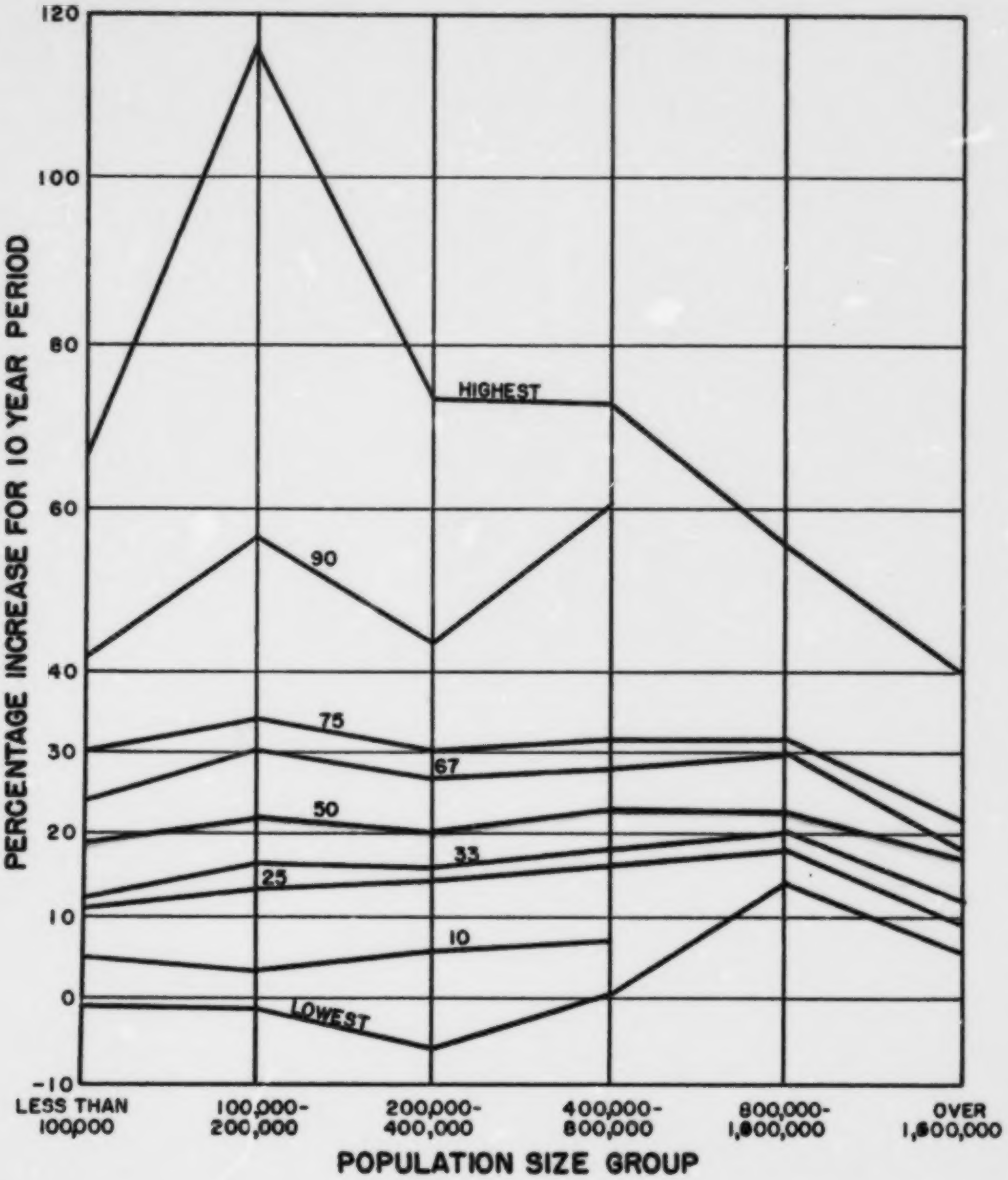

FIGURE 2

Table 7
Range in the Percentage Rate of Growth of SMA's of Varying Size Groups for 1910-20, 1920-30, 1940-50, 1950-60

	No.	Percentile Highest	90	75	67	50	33	25	10	Lowest
Under 100,000:										
1910-1920	15	51		25	23	22	13	12		1
1920-1930	16	56	49	38	24	15	10	9	0	-5
1940-1950	20	79	42	30	27	17	16	15	7	3
1950-1960	18	69	32	27	22	17	10	8	3	-7
Average		64	41	30	24	18	12	11	5	-2
100-200,000:										
1910-1920	32	164	60	41	33	23	17	13	9	1
1920-1930	47	92	68	31	29	18	11	9	-1	-7
1940-1950	54	78	55	33	28	22	18	14	3	-1
1950-1960	62	123	45	32	30	24	21	16	2	-3
Average		116	57	34	30	22	17	13	3	-2
200-400,000:										
1910-1920	23	37	33	28	27	21	19	18	12	7
1920-1930	32	45	38	29	26	18	14	12	4	-8
1940-1950	42	92	52	31	29	20	13	11	4	-15
1950-1960	47	120	47	30	25	19	16	14	4	-12
Average		73	43	30	27	20	16	14	6	-7
400-800,000:										
1910-1920	15	113		30	28	24	18	17		5
1920-1930	12	42		24	22	21	18	16		10
1940-1950	19	53	42	36	28	22	15	12	4	-11
1950-1960	28	86	79	40	35	25	21	18	11	-6
Average		73	60	32	28	23	18	16	7	0
800-1,600,000:										
1910-1920	2	20				16				13
1920-1930	7	133		58	40	33	26	20		15
1940-1950	9	53		28	22	17	15	14		13
1950-1960	12	53		32	29	25	22	20		15
Average		55*		32*	30	23	21	18		14
Over 1,600,000:										
1910-1920	4	26				19				17
1920-1930	5	31				16				15
1940-1950	7	50		23	17	13	9	8		6
1950-1960	9	53		22	20	19	14	10		6
Average		40		22	18	17	12	9		6*

* Atypical cases adjusted

Of what predictive value is the above analysis? Simply this, it will give guidance to the upper and lower limit of the forecast. One can test the "reasonableness" of a given SMA attaining a specific forecast population given the trends of past SMA's in various size groups and given the particular SMA's past growth rate within these size classes. If a SMA has been growing slower than average, say about at the 25th percentile rank, then one can see what population it would attain if it stayed at this relative position. Or if one made a forecast, one can work backwards and determine at what relative rank this SMA would have to grow to reach this forecast and to see if this is "reasonable" in view of its past performance. One problem remains: Do SMA's tend to grow at a relatively constant trend compared to other cities in its size group? To spot-check this, we will review the performance of the cities you gentlemen represent. New York and Chicago are omitted because there are too few SMA's in this size category.

Table 8

Percentile Growth Rank of Select SMA's for Decades 1910-20, 1920-30, 1940-50, 1950-60

	1910-20	1920-30	1930-40	1940-50	1950-60
Atlanta	67	80	92	71	73
Austin	*	*	98	82	70
Cincinnati	10	45	45	34	11
Dallas	80	77	87	87	80
Denver	33	48	82	76	84
Houston	92	99	99	97	97
Kansas City	57	80	34	39	54
Salt Lake City	42	56	46	73	86
San Francisco-Oakland	77	50	64	94	72
Washington, D. C.	63	28	97	83	80

* Did not meet the requirement of a SMA.

Table 8 indicates that some SMA's grow at a relatively consistent trend compared to cities in its size group while others do not. However, the validity of a forecast within broad limits can be checked by these data. Atlanta, for example, fluctuated within the upper one-third of the fastest growing city in its size-class during the last 5 decades. Austin has been experiencing a relatively decreasing rate of increase. Houston, on the other hand, has consistently been the fastest growing SMA in its size group the last four decades.

These data establish rather broad boundary lines for projections. Atlanta has been hovering around the 75th percentile growth rate. The average growth rate would seem low, but likewise the 90th percentile would seem high. On the other hand, Cincinnati has never grown as fast as the average. It would seem from its past record, and in the absence of radically changed conditions, that to select a growth rate for Cincinnati that would be above average would not be tenable.

In order to make projections of the probable range of growth on the basis of the procedure just discussed, it will be necessary to project the median and the percentile range in growth rate of the various SMA size categories. It is assumed that the decreasing rate of SMA growth will influence all percentile growth rates the same relative amount. These projected growth rates are tabulated in Table 9.

An example of the use of Table 9 to project a SMA follows. Table 8 shows that Dallas SMA fluctuated between the 77th and 87th percentile. What would be the range in the 2010 projection if one assumes the upper limit would be that paralleling the projected 90th percentile growth rate and the lower limit would parallel the 75th percentile.

Table 10

Projection of Dallas
(Using projected 90th percentile growth rate)

Year	Population	Growth Rate	Population	Year
1960	1,071,003	137.8	1,476,000	1970
1970	1,476,000	135.6	2,001,000	1980
1980	2,001,000	125.1	2,504,000	1990
1990	2,504,000	123.4	3,089,000	2000
2000	3,089,000	121.8	3,763,000	2010

(Using projected 75th percentile growth rate)

Year	Population	Growth Rate	Population	Year
1960	1,071,003	130.2	1,394,000	1970
1970	1,394,000	128.5	1,792,000	1980
1980	1,792,000	118.4	2,122,000	1990
1990	2,122,000	117.2	2,486,000	2000
2000	2,486,000	116.0	2,884,000	2010

One enters the table with three arguments; SMA size, percentile growth rate, and decade. In this table one finds that SMA's ranging from 800,000 - 1,600,000 (Dallas was 1,071,003 in 1960) in the 1960-70 decade are predicted to grow 37.8 per cent during the decade (if they grow at the 90th percentile growth rate). During the following decade the rate is 35.6 per cent. By 1980 Dallas SMA is over 1,600,000, so one drops down to the category "over 1,600,000" and uses the growth rates of 25.1 per cent, 23.4 per cent, and 21.8 per cent for the next three decades. The same is repeated for the 75th percentile growth rate. The calculations are illustrated in Table 10.

What is the reliability of these projections? The Bureau of the Census states, "There is no approved body of knowledge which justifies confident predictions for 15 years or more into the future." This being the case, what claim to fame has this method? What accuracy does it purport to have? The writer devised this procedure in an attempt to establish limits within which a forecast would seem "reasonable". The validity cannot be checked, of course, but it can be compared to other techniques.

How does this projection compare with others? The RFF projection for the year 2000 was 2,950,000 (corrected to include the addition of 3 more counties to the Dallas SMA) based upon the United States total of 380,000,000 in 2010, which is assumed here. The projection by the Bureau of Census for 2000 (adjusted to for the same assumed national population) was approximately 2,860,000. The projections proposed by the writer indicate a low of 2,486,000 and a hig of 3,089,000, for an average of 2,788,000.

Another check is to work "backwards". A population as high as 9,000,000 has been forecast for Houston SMA from a base of 1,236,704 in 1960. Is this "reasonable"? To attain this population growth in 50 years, Houston SMA would have to increase 50 per cent every 10 years. Although this rate of increase had been attained in the 1950-60 decade by both Houston and Los Angeles, the fastest growing SMA's in the two largest size categories (see Table 7), it seems unlikely that a growth rate of that magnitude can be sustained for reasons mentioned earlier. If Houston SMA is assumed to continue to grow at the highest growth rate indicated on Table 9, a population forecast of 6,502,000 would seem more reasonable.

This methodology is in the nature of a hypothesis. It seems to give guidance. Nothing more is claimed.

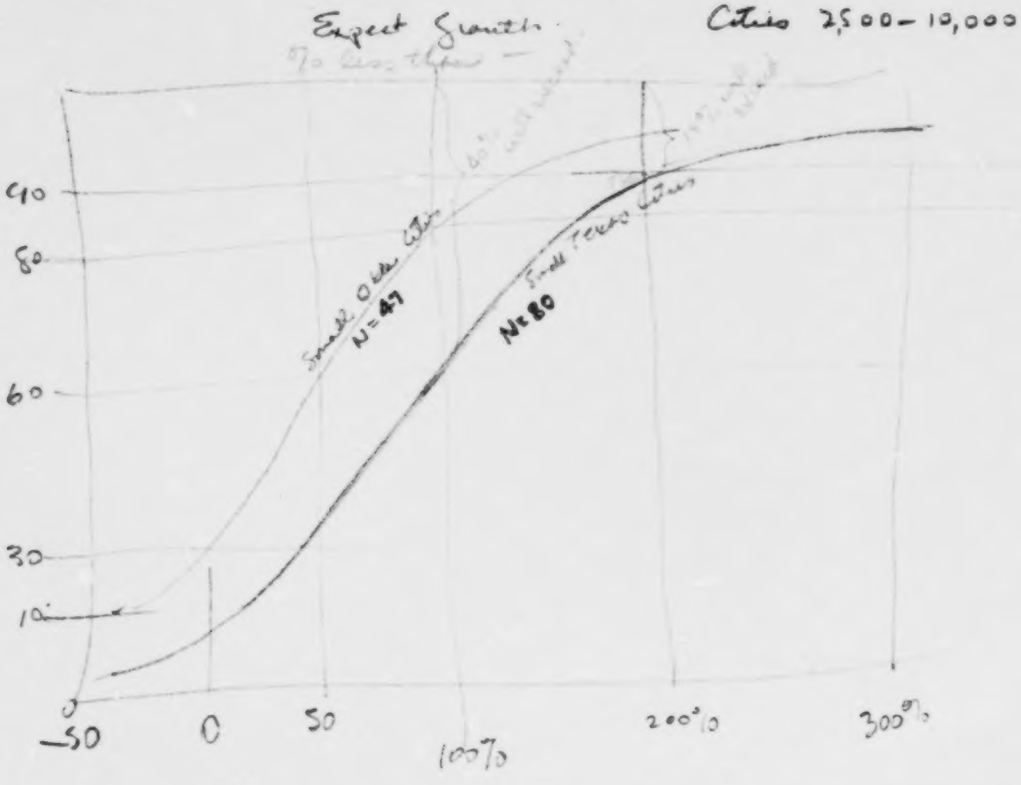

Table 9
Forecast Range in Percentage Growth Rates for SMA's of Various Size-Classes
1960-2010

	Percentile								
	Highest	90	75	67	50	33	25	10	Lowest
Under 100,000 to 800,000:									
1950-1960	75	50	32	29	23	18	15	5	0
1960-1970	70.8	47.3	30.2	27.4	21.7	17.0	14.2	4.7	0
1970-1980	66.7	44.5	28.5	25.8	20.5	16.0	13.4	4.4	0
1980-1990	62.6	41.8	26.7	24.3	19.2	15.1	12.5	4.2	0
1990-2000	58.5	39.0	25.0	22.7	18.0	14.1	11.7	3.9	0
2000-2010	54.4	36.3	23.2	21.1	16.7	13.1	10.9	3.6	0
800,000 to 1,600,000:									
1950-1960	55	40	32	29	23	20	18	16	14
1960-1970	52.0	37.8	30.2	27.4	21.7	18.9	17.0	15.1	13.2
1970-1980	49.0	35.6	28.5	25.8	20.5	17.8	16.0	14.2	12.5
1980-1990	45.9	33.4	26.7	24.3	19.2	16.7	15.1	13.4	11.7
1990-2000	42.9	31.2	25.0	22.7	18.0	15.6	14.1	12.5	11.0
2000-2010	39.9	29.0	23.2	21.1	16.7	14.5	13.1	11.6	10.2
Over 1,600,000:									
1950-1960	45	30	22	19	18	13	9	8	6
1960-1970	42.5	28.4	20.8	18.0	17.0	12.3	8.5	7.6	5.7
1970-1980	40.1	26.7	19.6	16.9	16.0	11.6	8.0	7.1	5.3
1980-1990	37.6	25.1	18.4	15.9	15.1	10.8	7.5	6.7	5.0
1990-2000	35.2	23.4	17.2	14.8	14.1	10.1	7.0	6.2	4.7
2000-2010	32.7	21.8	16.0	13.8	13.1	9.4	6.5	5.8	4.4

The mean associated with the above medians is 24.5 per cent.
The mean growth in 2010 is assumed to be 17.8 per cent.

The percentile growth rates therefore is reduced by $24.5/\overline{17.8}$ or 72.6 per cent by 2010. The intervening years were reduced by arithmetic progression.

Summary and Conclusions

1. There is no approved body of knowledge that justifies confident population predictions for 15 years or more into the future. Nevertheless, forecasts must be made. This paper summaries the trends for Standard Metropolitan Statistical Areas during the last 50 years, and suggests limits of probable growth trends for each SMA in the Nation.

2. Data of population trends of the last 50 years show these trends:

   a. The total SMA population has been increasing at relatively constrant rate.

   b. Net migration flows from the Non-SMA to the SMA, therefore, the SMA is becoming a relatively larger part of the total population.

   c. The median growth rates and the deviations from the median of SMA's between 100,000 and 1,600,000 show marked similarity.

   d. Although there is considerable variation in the rate of growth among SMA's in the same size group, the relative variability in the growth rates of individual SMA's is considerably less.

3. Past trends suggest that:

   a. The growth rate of the total SMA population will decrease because the migration from the Non-SMA's will contribute relatively less in its growth in the future.

   b. Since many SMA's grow at a relatively consistent trend in relation to the growth rate of other SMA's in their size category the growth rates for individual SMA's can be projected.

4. The past rate of growth and the relative dispersion in the rate of growth is shown for all SMA's of the Nation in the appendix. From these data, the forecaster may make a judgment as to the limits of the most probable future growth rate of a given SMA. Table 9 summarizes the projected growth rates that can be used for projection.

APPENDIX

Population, Percentage Population Change, and Percentile Growth Rank of Standard Metropolitan Statistical Areas of the United States, 1910-1960

Note: The population for Standard Metropolitan Statistical Areas for all decades has been adjusted for changes in boundaries; that is, the population of 1950 and previous decades is that residing in the SMSA's as defined in 1960. The first row of figures is the population, the second row is the percentage change in population for the decade, and the third row is the percentile growth rank. The figures in parentheses indicate that the SMSA did not meet the qualifications to be defined as SMSA in 1950.

	1910		1920		1930		1940		1950		1960
Abilene, Texas									(85,517)	(39.4)	119,178
Akron, Ohio	108,253	164.2 98	286,065	20.3 52	344,131	-1.4 7	339,405	20.8 54	410,032	24.1 41	508,788
Albany, Georgia									(43,617)	(71.5)	74,787
Albany, Schenectady, Troy, New York	446,094	5.1 3	468,627	11.0 11	520,069	2.1 24	531,249	10.9 18	589,359	10.7 9	652,205
Albuquerque, New Mexico									145,673	78.6 96	260,162
Allentown, Bethleham, Easton, Pa. & N. J.	289,686	19.7 41	346,664	12.9 27	391,516	1.3 23	396,673	10.4 20	437,824	12.1 13	490,660
Altoona, Pennsylvania	108,858	17.9 36	128,334	9.0 27	139,840	0.4 13	140.358	-0.6 1	139,514	-2.5 2	136,027
Amarillo, Texas							61,450	41.8 87	87,140	69.4 97	147,621
Ann Arbor, Michigan									134,606	27.8 57	172,016

	1910		1920		1930		1940		1950		1960
Asheville, North Carolina					97,937	11.0 80	108,755	14.4 25	124,403	2.4 10	127,367
Atlanta, Georgia	273,288	27.6 67	348,580	32.6 80	462,386	20.9 92	558,842	30.1 71	726,989	39.0 73	1,010,577
Atlantic City, New Jersey			83,914	48.8 91	124,823	-0.6 5	124,066	6.7 12	132,399	19.6 31	158,312
Augusta, Georgia - South Carolina			109,266	10.2 31	120,393	9.5 50	131,779	22.9 53	162,013	32.1 75	214,079
Austin, Texas					77,777	42.8 98	111,058	45.0 82	160,980	30.8 70	210,519
Bakersfield, California									(228,309)	(26.2)	288,127
Baltimore, Maryland	770,427	17.1 30	902,122	14.9 7	1,036,753	9.9 93	1,139,529	23.3 72	1,405,399	21.5 28	1,707,462
Baton Rouge, Louisiana									158,236	44.7 90	228,893
Bay City, Michigan									88,461	19.4 58	105,594

	1910		1920		1930		1940		1950		1960
Beaumont, Port Arthur, Texas									235,650	29.4 73	304,826
Billings, Montana									(55,875)	(39.6)	78,001
Binghamton, Endicott, New York			113,610	29.4 71	147,022	12.7 60	165,749	11.4 14	184,698	14.6 22	211,705
Birmingham, Alabama	226,476	36.9 98	310,054	39.2 92	431,493	6.6 50	459,930	21.5 50	558,928	12.6 16	629,248
Boston, Massachusetts	1,602,023	16.7 12	1,868,859	16.0 50	2,168,566	3.4 50	2,242,978	7.5 21	2,410,572	6.5 6	2,566,732
Bridgeport, Connecticut	125,717	51.8 86	190,803	10.5 33	210,764	6.9 47	225,268	21.5 58	273,723	21.7 52	333,042
Brockton, Massachusetts	94,866	12.3 30	106,526	1.1 14	107,668	-1.0 3	106,631	12.3 19	119,728	24.4 49	148,988
Brownsville, Harlingen, San Benito, Texas									(125,170)	(19.8)	149,901
Buffalo, New York	621,021	21.3 43	753,393	21.0 54	911,737	5.1 36	958,487	13.6 6	1,089,230	19.5 20	1,301,604

	1910		1920		1930		1940		1950		1960
Canton, Ohio	122,987	44.1 80	177,218	25.1 61	221,784	5.9 45	234,887	20.6 51	283.194	19.3 50	337,984
Cedar Rapids, Iowa					82,336	8.3 67	89,142	17.0 52	104,274	29.6 67	135,192
Champaign-Urbana, Illinois									(106,100)	(23.3)	130,813
Charleston, South Carolina	88,594	22.4 57	108,450	-6.8 1	101,050	19.8 83	121,105	36.1 81	164,856	27.2 56	209,757
Charleston, West Virginia					157,667	24.1 95	195,619	22.5 51	239,629	4.4 10	250,284
Charlotte, North Carolina					127,971	18.6 81	151,826	29.8 71	197,052	37.5 86	270,966
Chattanooga, Tennessee - Georgia			139,324	33.3 82	185,703	13.9 75	211,502	16.5 42	246,453	13.3 22	279,314
Chicago, Illinois	2,702,465	25.6 87	3,394,996	31.1 90	4,449,646	2.7 21	4,569,643	13.3 50	5,177,868	19.2 61	6,171,517
Cincinnati, Ohio - Kentucky	590,456	6.5 10	628,999	20.2 45	756,281	4.1 45	787,044	14.9 34	904,402	18.1 11	1,067,669

	1910		1920		1930		1940		1950		1960
Cleveland, Ohio	660,352	47.2 83	972,162	27.9 36	1,243,129	1.9 7	1,267,270	15.6 39	1,465,511	21.9 37	1,786,740
Colorado Springs, Colorado									(74,523)	(91.4)	142,643
Columbia, South Carolina					124,161	13.4 74	140,837	32.7 75	186,844	38.1 88	257,971
Columbus, Georgia - Alabama							126,407	34.9 79	170,541	26.7 54	216,155
Columbus, Ohio	221,567	28.2 72	283,951	27.2 73	361,055	7.7 58	388,712	29.5 68	503,410	35.1 66	680,183
Corpus Christi, Texas							92,661	78.6 97	165,471	32.4 77	219,028
Dallas, Texas	269,656	30.2 80	351,215	30.6 77	458,629	14.9 87	527,145	41.0 87	743,501	44.0 80	1,071,003
Davenport, Rock Island, Moline, Iowa - Illinois			166,249	5.6 18	175,523	12.8 62	198,071	18.3 36	234,256	14.2 24	267,414
Dayton, Ohio	238,543	21.2 50	289,181	23.8 64	358,041	7.2 50	383,975	35.1 80	518,642	32.9 62	689,339

	1910		1920		1930		1940		1950		1960
Decatur, Illinois					81,731	3.6 37	84,693	16.7 47	98,853	18.8 53	117,470
Denver, Colorado	277,097	19.4 33	330,948	16.3 48	385,019	15.6 82	445,206	37.5 76	612,128	51.2 84	925,569
Des Moines, Iowa	110,438	39.5 73	154,029	12.2 37	172,837	13.3 70	195,835	15.4 27	226,010	17.2 44	264,895
Detroit, Michigan	613,773	112.7 97	1,305,798	66.7 79	2,177,343	9.2 64	2,377,329	26.9 79	3,016,197	24.1 83	3,743,447
Dubuque, Iowa									71,337	11.8 36	79,740
Duluth, Superior, Minnesota - Wisconsin	210,696	21.6 54	256,162	-1.9 5	251,179	1.1 18	254,036	-0.5 8	252,777	7.9 16	272,674
Durham, North Carolina					67,196	19.4 89	80,244	26.7 67	101,639	11.3 19	113,083
El Paso, Texas			101,877	29.2 69	131,597	-0.4 7	131,067	48.8 84	194,968	59.9 94	311,759
Erie, Pennsylvania	115,517	32.9 67	153,536	14.2 44	175,277	3.2 23	180,889	21.3 45	219,388	12.8 20	247,538

	1910		1920		1930		1940		1950		1960
Eugene, Oregon									(125,776)	(27.8)	160,742
Evansville, Indiana - Kentucky	106,790	12.3 20	119,902	16.4 46	139,615	13.0 64	157,803	21.1 44	191,137	2.9 12	196,634
Fall River, Massachusetts - Rhode Island	131,031	1.8 5	133,348	0.2 12	133,599	1.2 17	135,137	1.6 5	137,298	0.1 6	137,420
Fargo, Moorhead, North Dakota - Minnesota									(89,240)	(17.6)	104,983
Fitchburg, Leominster, Massachusetts									(74.943)	(9.4)	81,951
Flint, Michigan			125,668	68.4 90	211,641	7.7 55	227,944	18.9 49	270,963	36.7 84	370,303
Fort Lauderdale, Hollywood, Florida									(83,933)	(292.5)	329,406
Fort Smith, Arkansas									64,202	3.5 14	66,454
Ft. Wayne, Indiana	93,386	22.4 50	114,303	28.4 65	146,743	5.7 36	155,084	18.5 38	183,722	25.7 52	230,963
Fort Worth, Texas	143,032	32.9 70	190,086	21.5 54	230,870	10.8 69	255,905	53.4 92	392,643	42.1 88	557,864

	1910		1920		1930		1940		1950		1960
Fresno, California					144,379	23.7 93	178,565	54.9 90	276,515	30.5 78	360,962
Gadsden, Alabama									93,892	2.3 8	96,048
Galveston, Texas City, Texas					64,401	26.0 93	81,173	39.3 82	113,066	22.2 41	138,156
Gary, Hammond, East Chicago, Indiana			180,213	57.7 88	284,131	13.0 77	321,031	27.2 65	408,228	40.1 77	571,799
Grand Rapids, Michigan	159,145	15.0 27	183,041	31.4 78	240,511	2.4 28	246,338	17.0 44	288,292	25.1 67	360,574
Great Falls, Montana									(53,027)	(38.0)	73,203
Green Bay, Wisconsin									98,314	26.7 75	124,536
Greensboro, High Point North Carolina					133,010	15.7 77	153,916	24.1 55	191,057	28.5 60	245,578
Greenville, South Carolina									168,152	24.4 51	209,227
Hamilton, Middletown, Ohio					114,084	5.4 32	120,249	22.4 49	147,203	34.6 83	198,166

	1910		1920		1930		1940		1950		1960
Harrisburg, Pennsylvania	190,631	11.0 14	211,694	10.3 17	233,467	8.0 61	252,216	15.9 39	292,241	17.3 48	342,664
Hartford, Connecticut	172,927	31.8 64	227,963	27.0 70	289,561	8.2 64	313,192	29.8 70	406,534	28.6 59	522,735
Houston, Texas	115,693	61.3 92	186,667	92.5 99	359,328	47.2 99	528,961	52.5 97	806,701	53.3 97	1,236,704
Huntington, Ashland, W. Virginia - Kentucky-Oklahoma			160,579	31.0 73	210,382	7.3 53	225,668	8.9 15	245,795	2.8 7	252,780
Huntsville, Alabama									(72,903)	(60.0)	116,612
Indianapolis, Indiana	263,661	32.0 85	348,061	21.4 58	422,666	9.1 71	460,926	19.7 45	551,777	25.1 48	690,162
Jackson, Michigan					92,304	0.9 15	93,108	15.9 32	107,925	21.3 38	130,943
Jackson, Mississippi							107,273	32.5 73	142,164	31.2 72	186,574
Jacksonville, Florida	75,163	51.1 97	113,540	37.0 84	155,503	35.1 97	210,143	44.7 85	304,029	47.4 90	448,272
Jersey City, New Jersey	537,231	17.1 23	629,154	9.8 2	690,730	-5.6 3	652,040	-0.7 8	647,437	-6.2 2	607,250

	1910		1920		1930		1940		1950		1960
Johnstown, Pennsylvania	233,848	19.7 37	279,951	1.4 8	283,910	5.1 39	298,416	-2.4 6	291,354	-4.0 5	279,662
Kalamazoo, Michigan					91,368	9.5 76	100,085	26.6 60	126,707	33.5 81	169,151
Kansas City, Missouri - Kansas	422,180	25.3 57	528,833	25.9 80	665,655	3.2 34	686,643	18.6 39	814,357	27.0 54	1,034,150
Kenosha, Wisconsin					63,277	0.4 11	63,505	18.5 57	75,238	32.4 92	99,609
Knoxville, Tennessee			160,024	31.0 76	209,613	17.4 91	246,088	37.0 82	337,105	8.2 18	364,665
Lake Charles, Louisiana									(89,635)	(58.8)	142,307
Lancaster, Pennsylvania			173,797	13.3 39	196,882	7.9 42	212,504	10.5 25	234,717	16.7 41	273,862
Lansing, Michigan			134,041	28.7 67	172,489	11.0 52	191,411	27.6 64	244,159	22.6 54	299,386
Laredo, Texas									56.141	15.5 42	64,857

	1910		1920		1930		1940		1950		1960
Las Vegas, Nevada									(48,289)	(159.8)	125,466
Lawrence, Haverhill, Massachusetts - New Hampshire	159,828	15.3 30	184,212	-3.2 5	178,230	0.1 9	178,404	2.3 6	182,442	3.4 14	188,663
Lawton, Oklahoma									(55,165)	(61.9)	89,320
Lewiston, Auburn, Maine									(68,426)	(2.3)	69,967
Lexington, Kentucky									100,746	28.8 62	129,722
Lima, Ohio									88,183	16.6 47	102,785
Lincoln, Nebraska			85,902	16.8 59	100,324	0.3 11	100,585	19.0 42	119,742	29.0 65	154,474
Little Rock, North Little Rock, Arkansas			109,464	25.8 63	137,727	13.3 72	156,085	26.0 58	196,685	21.7 40	239,460
Lorain, Elgria, Ohio									148,162	45.7 91	215,822
Los Angeles, Long Beach, California	538,567	85.3 90	997,830	133.2 93	2,327,166	25.3 93	2,916,403	49.8 93	4,367,911	52.7 94	6,668,975

	1910		1920		1930		1940		1950		1960
Louisville, Kentucky - Indiana	323,473	7.1 2	346,411	21.5 61	420,769	7.3 61	451,473	27.8 66	576,900	24.6 45	718,685
Lowell, Massachusetts	122,133	8.8 8	132,861	-4.4 3	126,991	4.4 26	132,633	2.5 8	135,987	15.5 23	157,083
Lubbock, Texas									101,048	51.6 93	153,140
Lynchburg, Virginia									(96,936)	(13.6)	110,108
Macon, Georgia			93,268	-5.3 3	88,322	7.7 63	95,086	42.0 92	135,043	32.5 78	178,917
Madison, Wisconsin					112,737	15.9 79	130,660	29.6 69	169,357	30.8 69	221,595
Manchester, New Hampshire	72,642	11.2 17	80,775	-0.1 9	80,673	1.6 24	81,932	7.9 12	88,370	6.2 19	93,889
Memphis, Tennessee	191,430	16.6 33	223,216	37.3 89	306,482	16.9 88	358,250	34.7 77	482,393	28.5 55	619,722
Meriden, Connecticut									(44,088)	(15.6)	50,966
Miami, Florida					142,955	87.3 99	267,739	84.9 96	495,084	86.2 98	921,625

	1910		1920		1930		1940		1950		1960
Midland, Texas									(25,785)	(161.9)	67,540
Milwaukee, Wisconsin	470,287	23.8 50	582,061	33.6 89	777,621	6.7 55	829,629	15.3 28	956,948	23.8 45	1,184,806
Minneapolis, St. Paul, Minnesota	620,837	17.3 37	728,327	21.1 63	882,266	9.6 79	967,367	19.0 61	1,151,053	28.1 63	1,474,149
Mobile, Alabama	80,854	23.8 70	100,117	18.2 50	118,363	19.9 87	141,974	62.8 95	231,105	35.3 80	312,771
Monroe, Louisiana									(74,713)	(37.7)	102,889
Montgomery, Alabama					98,671	16.0 85	114,420	21.5 47	138,965	21.3 36	168,539
Muncie, Indiana									90,252	22.1 69	110,239
Muskegon, Muskegon Heights, Michigan									(121,545)	(22.5)	148,950
Nashville, Tennessee	149,478	12.3 23	167,815	32.8 80	222,854	15.4 80	257,267	25.1 63	321,758	22.6 56	394,338
Newark, New Jersey	727,787	28.5 70	934,940	33.6 64	1,249,167	3.4 21	1,291,416	13.7 17	1,468,458	14.6 2	1,682,882

	1910		1920		1930		1940		1950		1960
New Bedford, Massachusetts	110,537	27.2 58	140,641	-0.8 10	139,557	-1.1 1	138,073	2.8 10	141,984	0.2 7	142,257
New Britain, Connecticut			76,168	16.3 53	88,550	2.2 28	90,499	15.2 17	104,251	23.4 46	128,642
New Haven, Connecticut	164,702	23.8 52	203,850	14.0 42	232,327	5.1 42	244,294	10.4 23	269,715	14.5 27	308,786
New Orleans, Louisiana	362,599	14.1 20	413,750	22.1 71	505,306	9.3 76	552,244	24.1 61	685,405	25.7 52	861,299
Newport News, Hampton, Virginia									(154,977)	(43.9)	223,029
New York, New York	5,276,879	18.4 37	6,246,398	27.7 70	7,975,100	9.2 79	8,706,917	9.8 36	9,555,943	11.0 28	10,602,382
Norfolk, Portsmouth, Virginia	164,912	50.9 83	248,872	-7.7 2	229,635	12.8 74	258,927	72.3 94	446,200	21.4 34	541,494
Norwalk, Connecticut									(65,685)	(46.8)	96,397
Odessa, Texas									(42,102)	(112.7)	89,542

	1910		1920		1930		1940		1950		1960
Ogden, Utah									83,319	31.7 86	109,741
Oklahoma City, Oklahoma	127,576	23.8 55	157,984	73.9 93	274,801	8.9 66	299,216	31.2 75	392,439	29.6 76	508,581
Omaha, Nebraska - Iowa	233,652	17.9 28	275,444	13.7 33	313,272	3.8 34	325,153	12.7 32	366,395	24.5 63	456,164
Orlando, Florida									141,833	123.3 99	316,772
Paterson, Clifton, Passaic, New Jersey	353,904	32.8 89	469,877	42.0 97	667,106	7.8 66	718,999	21.9 55	876,232	35.1 89	1,183,514
Pensacola, Florida									(131,260)	(54.0)	202,140
Peoria, Illinois	134,282	11.9 17	150,250	24.7 59	187,426	13.0 66	211,736	18.3 46	250,512	14.6 29	287,115
Philadelphia, Pennsylvania - New Jersey	2,268,209	19.7 62	2,714,271	15.6 30	3,137,040	2.0 7	3,199,637	14.7 64	3,671,048	17.2 39	4,301,283
Phoenix, Arizona							186,193	78.2 99	331,770	98.2 97	657,688
Pittsburg, Pennsylvania	1,471,800	19.6 *	1,759,989	15.0 10	2,023,269	2.9 36	2,082,556	6.3 7	2,213,236	8.1 17	2,392,086

	1910		1920		1930		1940		1950		1960
Pittsfield, Massachusetts									66,567	9.7 31	73,049
Portland, Maine	77,668	17.2 43	91,055	9.7 28	99,874	6.7 54	106,569	12.5 21	119,942	-0.2 4	119,677
Portland, Oregon	303,829	22.7 59	372,777	35.5 86	505,037	-0.7 13	501,275	40.6 82	704,829	16.2 23	818,776
Providence, Rhode Island	542,591	8.4 17	588,090	15.2 20	677,195	2.7 29	695,253	9.3 13	760,202	6.6 5	810,145
Provo, Orem, Utah									(81,912)	(30.4)	106,777
Pueblo, Colorado					66,038	4.3 46	68,870	31.0 77	90,188	30.3 81	117,547
Racine, Wisconsin			78,961	14.3 47	90,217	4.2 41	94,047	16.5 37	109,585	28.4 59	140,745
Raleigh, North Carolina									136,450	23.7 48	168,835
Reading, Pennsylvania	183,222	9.6 11	200,854	15.4 45	231,717	4.4 36	241,884	5.7 11	255,740	7.4 14	274,638
Reno, Nevada									(50,205)	(66.7)	83,700

	1910		1920		1930		1940		1950		1960
Richmond, Virginia	172,364	22.5 45	211,135	13.3 30	239,288	11.2 72	266,185	23.2 61	328,050	23.9 61	406,601
Roanoke, Virginia			73,237	42.7 78	104,495	7.4 40	112,184	18.9 40	133,407	18.4 28	157,977
Rochester, New York	283,212	24.3 63	352,034	20.4 55	423,881	3.4 39	438,230	11.3 24	487,632	19.5 27	582,777
Rockford, Illinois			90,929	29.1 72	117,373	3.2 25	121,178	25.8 56	152,385	37.0 85	208,701
Sacramento, California			91,029	56.0 97	141,999	20.0 89	170,33	62.7 94	277,140	80.5 95	500,204
Saginaw, Michigan	89,290	12.3 23	100,286	20.4 52	120,717	8.1 44	130,468	17.7 32	153,515	23.3 44	189,237
St. Joseph, Missouri	93,020	0.7 3	93,684	5.3 16	98,633	-4.6 2	94,067	2.9 2	96,826	-7.2 3	89,897
St. Louis, Missouri - Illinois	1,031,736	13.1 *	1,166,432	18.9 21	1,387,075	5.6 50	1,464,111	17.4 50	1,719,288	19.0 50	2,046,477
Salt Lake City, Utah	131,426	21.2 42	159,282	21.9 56	194,102	9.0 46	211,623	29.9 73	274,895	38.9 86	381,961

	1910		1920		1930		1940		1950		1960
San Angelo, Texas									58,929	7.6 25	63,415
San Antonio, Texas	119,676	68.9 95	202,096	44.7 98	292,533	15.6 85	338,176	48.0 87	500,460	36.4 70	682,481
San Bernardino, Riverside, Ontario, California									451,688	77.3 87	800,865
San Diego, California			112,248	86.8 97	209,659	38.0 96	289,348	92.4 99	556,808	79.7 91	1,000,856
San Francisco, Oakland, California	773,975	30.4 77	1,009,467	33.5 50	1,347,772	8.5 64	1,461,804	53.3 94	2,240,767	21.6 72	2,725,841
San Jose, California					145,118	20.6 91	174,949	66.1 97	290,547	119.6 99	638,054
Santa Barbara, California									(98,220)	(70.9)	167,883
Savannah, Georgia	79,690	25.5 83	100,032	5.4 16	105,431	11.9 56	117,970	28.4 68	151,481	23.1 43	186,424
Scranton, Pennsylvania	259,570	10.3 7	286,311	8.4 14	310,397	-3.0 1	301,243	-14.6 1	257,396	-9.4 3	233,271

	1910		1920		1930		1940		1950		1960
Seattle, Washington	343,847	32.9 93	456,963	18.7 37	542,378	9.5 82	593,734	42.2 92	844,572	30.1 71	1,098,741
Shreveport, Louisiana					153,058	19.8 85	183,365	18.2 34	216,686	29.3 71	280,086
Sioux City, Iowa			92,171	10.3 34	101,669	1.9 19	103,627	0.3 3	103,917	3.8 15	107,863
Sioux Falls, South Dakota									70,910	21.2 64	85,951
South Bend, Indiana	84,312	22.5 63	103,304	54.9 86	160,033	1.1 15	161,823	26.7 62	205,058	16.0 37	237,874
Spokane, Washington	139,404	1.4 2	141,289	6.5 20	150,477	9.4 48	164,652	34.6 77	221,561	25.1 65	277,261
Springfield, Illinois	91,024	10.1 10	100,26	11.4 35	111,733	5.5 34	117,912	11.5 18	131,484	11.1 17	146,096
Springfield, Missouri					82,929	9.2 72	90,541	15.8 27	104,823	19.6 30	125,376
Springfield, Ohio			80,728	12.6 41	90,936	5.2 50	95,647	16.7 42	111,661	17.1 27	130,701

	1910		1920		1930		1940		1950		1960
Springfield, Chicopee, Holyoke, Massachusetts	263,147	28.5 76	338,033	11.4 23	376,699	-1.3 9	371,972	11.2 27	413,494	15.3 20	476,588
Stamford, Connecticut									134,896	31.4 73	177,305
Steubenville, Weirton, Ohio - West Virginia									(157,787)	(6.7)	168,293
Stockton, California							134,207	49.6 86	200,750	23.8 59	248,622
Syracuse, New York	311,251	13.1 11	352,045	13.9 39	401,041	1.2 18	405,981	14.6 29	465,114	20.9 30	562,362
Tacoma, Washington	120,812	19.3 39	144,127	13.7 41	163,842	11.1 54	182,081	51.5 88	275,876	16.2 39	320,438
Tampa, St. Petersburg, Florida			116,522	85.1 95	215,668	26.1 93	272,000	50.4 89	409,143	85.7 95	759,780
Terre Haute, Indiana	87,930	14.0 37	100,212	-1.3 7	98,861	0.9 20	99,709	5.5 7	105,160	2.4 9	107,668
Texarkana, Texas-Arkansas									(94,580)	(-3.6)	91,231

	1910		1920		1930		1940		1950		1960
Toledo, Ohio	192,728	43.1 77	275,721	26.1 67	347,709	1.0 15	344,333	14.9 37	395,551	14.9 31	454,472
Topeka, Kansas			69,159	23.2 66	85,200	7.1 59	91,247	15.5 22	105,418	33.1 80	140,355
Trenton, New Jersey	125,657	27.2 61	159,881	17.1 48	187,143	5.4 30	197,318	16.5 31	229,781	15.7 35	265,766
Tucson, Arizona									141,216	85.1 98	261,428
Tulsa, Oklahoma			208,039	43.7 95	299,023	-2.9 4	290,368	12.9 33	327,900	26.0 69	413,018
Tuscaloosa, Alabama									(94,092)	(15.4)	108,613
Tyler, Texas									(74,701)	(15.4)	86,188
Utica, Rome, New York	210,513	17.7 24	247,795	6.0 11	262,769	0.1 12	263,163	8.0 13	284,262	15.5 33	328,255
Waco, Texas					98,682	3.3 33	101,898	27.8 66	130,194	13.9 20	148,336
Washington, D. C. - Maryland-Virginia	445,401	28.4 63	571,090	17.5 28	672,198	44.4 97	970,561	50.8 83	1,464,089	34.4 80	1,967,682

	1910		1920		1930		1940		1950		1960
Waterbury, Connecticut	98,332	25.4 77	123,309	9.1 29	134,505	3.2 21	138,779	11.4 16	154,656	16.3 25	179,902
Waterloo, Iowa							79,946	25.6 62	100,448	21.0 33	121,567
West Palm Beach, Florida									(114,688)	(95.8)	224,537
Wheeling, West Virginia-Ohio			189,766	8.9 24	206,627	1.1 20	208,918	-6.0 4	196,305	-3.5 1	189,490
Wichita, Kansas	73,095	26.2 90	92,234	47.8 84	136,330	5.1 28	143,311	55.1 92	222,290	56.3 93	347,406
Wichita Falls, Texas			78,165	7.6 22	84,100	-3.4 7	81,203	29.7 72	105,309	21.2 35	127,654
Wilkes, Barre, Hazleton, Pennsylvania	343,186	13.9 15	390,991	13.8 36	445,109	-0.8 8	441,518	-11.2 3	392,241	-11.9 1	345,695
Wilmington, Deleware - New Jersey	150,187	23.1 48	184,811	7.1 22	197,866	12.1 58	221,836	21.0 56	268,387	35.3 82	363,253
Wiston-Salem, North Carolina					111,681	13.2 68	126,475	15.5 29	146,135	28.8 64	188,229
Worchester, Massachusetts	205,564	19.8 46	246,347	10.7 20	272,704	1.4 26	276,453	9.6 18	303,037	6.4 12	322,438

	1910		1920		1930		1940		1950		1960
York, Pennsylvania					167,135	6.5 38	178,022	13.9 23	202,737	17.2 46	237,630
Youngstown, Ohio	168,917	60.0 89	270,230	32.9 83	359,205	3.7 31	372,566	11.8 30	416,544	21.8 38	507,557

GROWTH FACTORS IN ECONOMIC BASE STUDIES[1]

This paper is concerned with the application of growth factors to economic base studies and the consideration of whether the values for these factors can be standardized.

The term "growth factors" has been selected to refer to a class of terms which are used to describe some of the important changes in the relationships between parameters of the economy. Examples include the so-called productivity factor which describes the changing relationship between the output of an industry and the quantity of labor employed. To illustrate, if the productivity of the workers in a certain establishment increases over time and the output of the plant is to remain the same, then fewer workers will be required in the future or the same number of workers will work shorter hours.

Another example of a growth factor is the changing relationship between employment in primary (sometimes called basic or externally-oriented) industries and the number of service (sometimes called secondary or internally-oriented) industry employees that are required to serve them. When employment is converted to population, a third example of a growth factor is found in the changing relationship describing the number of persons in the population per worker.

As a first step in examining the nature of growth factors it is desirable to examine how they will be used. They will, of course, be a part of the economic study--more properly called the economic base analysis and forecast. Although such studies are made for a number of purposes, our interest in the economic study is usually as a tool to provide basic data and forecasts about water consumers, users of water resources, and contributors of pollution. By keeping such goals in mind the economic study can avoid getting into irrelevant areas or providing unnecessary detail. I think that we can agree that some of the more important statistics which should come out of the economic study would be population, employment, industrial output (for many, but not all, industries) and land use.

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[1] Prepared by John H. Davidson, U. S. Public Health Service, Portland, Oregon, March 1961.

In order to get a better look at the economic study and to recognize the role of growth factors it is helpful to construct a model. The construction of such a model is also one of the basic steps in preparing the economic study. It should be pointed out that many of the people who prepare economic base studies use the model technique without calling it such. The concept of a model, however, is particularly important because it assists in the recognition and definition of the important relationships between segments of the economy. The acknowledgment and understanding of the causes and effects of various economic features is basic to interpreting and forecasting the economy of a specific area. Such an understanding can frequently point the way to avoiding two dangerous over-simplifications frequently encountered in forecasting. These are (1) blind extrapolation of historical trends, and (2) assuming that the study area has exactly the same characteristics as the Nation and will maintain its same relative position. It should be recognized that the use of a model does not necessarily mean that an equation must be written. Many worthwhile economic studies are conducted on a much less formal basis, with the model being described in sentences rather than by a formula.

As a basis for the model we need to know some of the fundamental relationships between the facets of the economy which relate to the statistics we want to obtain. One important such relationship is indicated in the concept that some economic activities which involve employment of persons are of a primary nature and others are of a supporting nature. Although the distinctions are sometimes difficult to make, a very useful tool is derived by classifying all industries[1/] into either externally-oriented industry or internally-oriented industry and examining the numerical relationships between their respective employments.

It should be noted at this point that the reference to either external or internal orientation of industry has been selected to attempt to overcome some of the shortcomings of other such pairs of terms for industry as basic and non-basic, primary and secondary (or service), etc. These classifications can be briefly defined as follows:

> Externally-oriented industries depend on the particular resources or manufacturing opportunities of the area. These opportunities allow, in theory, for the production of goods in excess of the requirements of the community. The excess is exported from the area, and products from other areas are imported. The internally-oriented industries, in general, depend on the consumer needs of a community. They supply

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1/ The term "industries" is used in the broad sense to indicate all types of value-producing activities. These activities include those relating to both goods and services and not just to manufacturing.

goods and services sufficient for the community and grow when the community's externally-oriented industries develop.

When using this model approach, it should be recognized that the bigger the study area the less valid is the technique. As a ridiculous example, if the whole United States is considered, there is very little basis for making a distinction between primary industry and supporting industry because about 95 per cent of our national economic activity is for internal consumption. On a community or local area basis, however, it is typical to find about half the economic activity is internally-oriented and half is externally-oriented. The ratio between these two types of industry is usually a function of the size and diversity of the community's or area's economy. Depending upon the area, the ratio can vary from, say, 1/2 worker in internally-oriented industries per worker in externally-oriented industries in a rural area to a ratio of 2 or more in an urban area. The important point here is that from a forecast of externally-oriented industry one has a basis for deriving the extent of internally-oriented industry. In like fashion one can convert employment to population by multiplying the employment by the number of persons in the population per worker. This ratio will vary considerably for different areas but averages about 3 persons per worker. Although changes in this ratio over a period of time would be expected for various areas, it is interesting to note that the Department of Labor estimates[1/] of total labor force participation rates for 1975 are almost unchanged from the 1955 level.

[1/] Population and Labor Force Projections for the United States, 1960 to 1975, Bulletin No. 1242, U. S. Department of Labor, Bureau of Labor Statistics, June 1959.

A simplified expression of this model would be as follows:

(Externally-oriented industry workers)(K_1) = (Internally-oriented industry workers)

(Externally-oriented industry workers) + (Internally-oriented industry workers) = (Total workers)

(Total workers) x (K_2) = (Population)

where: K_1 is the ratio (for the study area and study period) between workers in internally-oriented industry to those in externally-oriented industry, and K_2 is the ratio of persons in the population per worker.

From this model, by assuming some average values for K_1 and K_2, one can develop a useful rule-of-thumb for estimating the effect on population of a new industry in a community. Assuming that $K_1 = 1$ and $K_2 = 3$, then one new worker in an externally-oriented industry would, on the average, add one new worker in an internally-oriented industry, and would bring about a total population increase of six persons, considering the families of each of the workers.

In the construction of a model as the basis for a forecast of the future economy, one of the major efforts would be the development of a forecast of the total workers in externally-oriented industry. This can be done by forecasting each of the major components of such industry. The forecast of these components usually includes the consideration of productivity of labor. As mentioned earlier, other factors such as the length of the work week might also affect the number of workers.

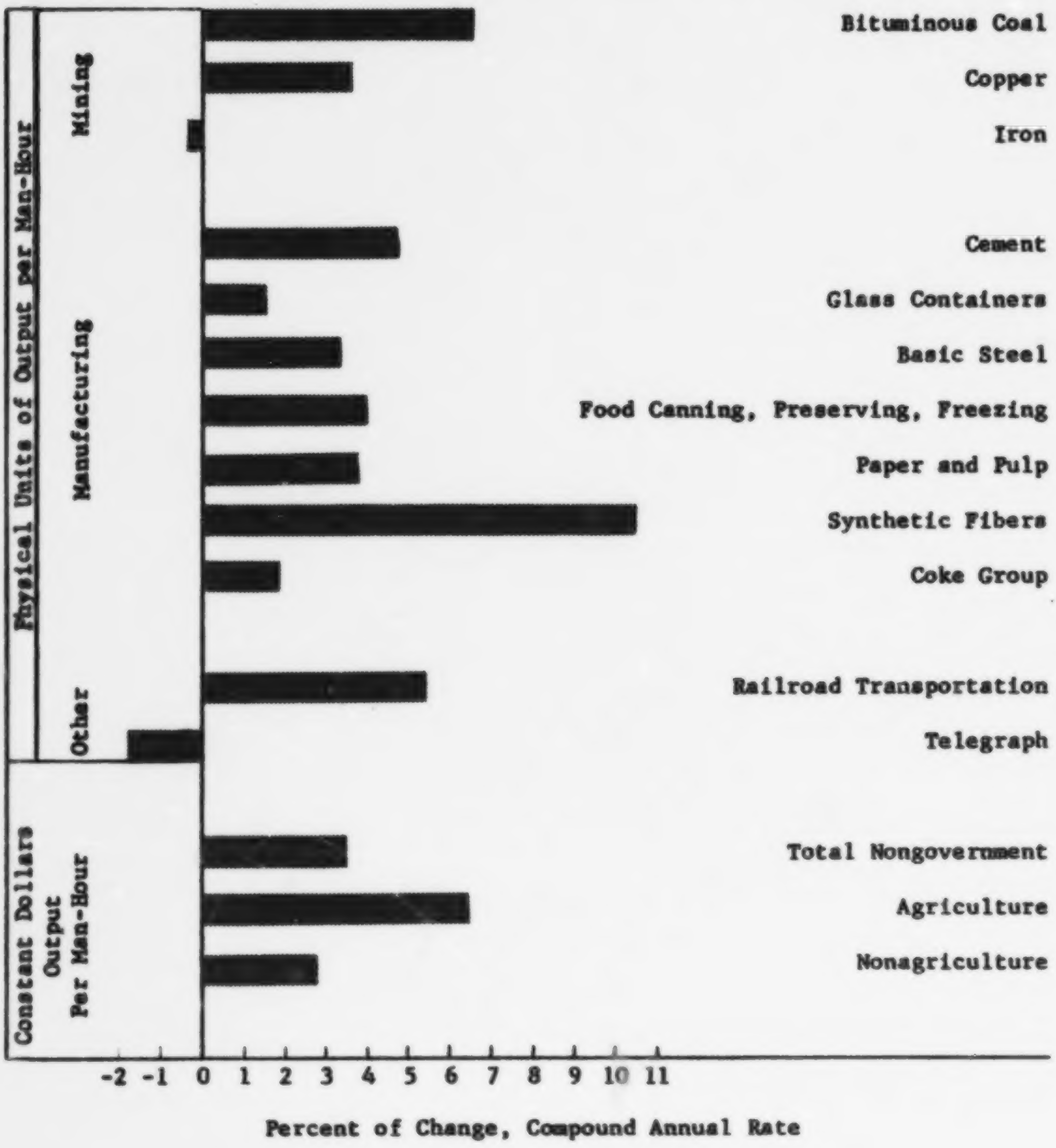
The measurement of productivity, for our purposes, is mainly a problem in estimating its relative change over time. The attached chart has been prepared to illustrate the annual rate of change for selected industries. The annual rates of change were based on two indicators of output. In the first part of the chart physical units of output were used. In the second part of the chart the output product was measured in constant dollars. The wide range of annual change among the selected industries should be noted.

The rate of annual change also varies considerably over time. A hasty measure of this can be derived from examination of the U. S. Bureau of Labor Statistics Index of total real private product per man-hour. For the period 1950-1959 its average annual increase amounted to 2.8 per cent, for the period 1947-1950 the annual increase was 4.5 per cent, and for 1941-1947 it was 1.0 per cent. Over the last 50 years the annual change of this index has averaged 2.2 per cent.

From this discussion and from the chart it should be obvious that the productivity factor varies considerably depending upon the industry and the time for which it is measured, and that this might have a considerable effect on the economic model. However, rather than digress any further at this time on the subject of constructing models of the economy, I have included as Appendix I some further notes about the construction of a model such as we are using in our studies of the Pacific Northwest.

With this background the question which prompted this paper can now be examined. This question was initially stated as follows:

Productivity Factors for Selected Industries in the Private Economy
Annual Rate of Change for Last Decade



Source: Computed from statistics in: Economic Forces in the U. S. A., U. S. Department of Labor, Bureau of Labor Statistics, May 1960, pages 118-120.

"Productivity increase factors--can they be standardized?" We have broadened this question by considering other related growth factors as well. Examination of the nature of the coefficients in the simple equation developed as a model of the economic base provides a logical answer to our question about standardization. Because these coefficients are developed from the study of areas with specific conditions they can generally only be applied to areas with similar conditions. Obviously, it would be wrong to use national factors for a local situation unless the local situation was completely typical of the Nation by having the same conditions of influence as the Nation. It is probably safe to say that national growth factors should only be used as guides in making economic studies of local areas. Growth factors, therefore, can only be standardized when the individual study areas are identical with standard conditions. Because this is not often likely, we must modify or develop growth factors to meet the situation found in the study area.

Even though this point of view precludes the preparation of a single set of factors to be plugged into all economic studies, I feel that the approach or methodology involved in making economic studies is more subject to standardization. Although it is not possible or desirable to lay out a cook-book approach that will serve all needs, it should be feasible for us to agree on the general principles and standards for such studies and then to work cooperatively toward the improvement of techniques and the sharing of basic information. Since I have taken the position that standardization of growth factors is not generally feasible, there is little opportunity for me to complete the use of my allotted time with the presentation of a tabulation of standard factors. In lieu of this, I am attaching as Appendix II a brief annotated bibliography of some interesting publications in this field which might provide some additional background on procedures and sources of information.

In addition, I wish to make a few brief comments about some of the influences to be considered in developing these various growth factors. One of the influences on the possible number of employees is the length of the work week. One simple rationalization that could eliminate further adjustments is to assume that the decrease of the work week will exactly offset the increased productivity due to such factors as automation. It should be considered, however, that any possible shortening of the work week will likely be greatest in manufacturing industries and will probably not occur at all in many industries, particularly small service industries.

The matter of productivity is of interest not only in regard to employees, but also with respect to the output of the land resource. We have witnessed in the last few decades some tremendous changes in the productivity of farm land. We have also seen a considerable mechanization of farming processes. In many areas, however, this latter has not decreased the number of persons employed on farms because there have been other changes, such as irrigation, which have resulted in more intensive use of land and an increase in the labor requirement of this land.

Increased productivity from forest land will probably be one of the dramatic changes to occur in the future economic base of the Pacific Northwest. Experiments now underway indicate that fertilization of forest areas and the application of genetic principles to tree harvesting and reforestation will have a tremendous effect on the productivity of this resource.

In conclusion, I would like to summarize some of the main areas to be examined in this paper. These are enumerated as follows:

1. Economic base studies are facilitated by the use of models which define the important relationships between segments of the economy.

2. The model generally contains the growth factors expressed as coefficients modifying the various basic statistics.

3. The growth factors can only be standardized when the individual study areas meet standard conditions; therefore, standardization of growth factors usually is not feasible.

4. Standardization of methodology is a feasible and worthwhile goal.

The model is usefully when it makes you think.

APPENDIX I

Notes on an Economic Model of Future Employment and Population in the Willamette River Basin of Oregon.

A. Introductory Notes

1. The model described in this appendix is not intended to be a complete description of the economy, but merely presents a procedure for analyzing employment. This procedure is particularly important, however, because employment can be, and frequently is, the common denominator for various parameters of the economy. Employment can also be utilized as the basis for both water use and pollution contribution studies.
2. The application of the model to a basin requires some judgment as to the size of the sub-area to be included. For convenience, the area to be covered in one model study should be relatively homogenous. It is planned in the Willamette Basin to make three model studies to cover the upper, middle, and lower sections of the Basin. Each of these sections has distinguishing economic characteristics.
3. Comparisons of the model's results with forecasts prepared by other means and with forecasts of the region or Nation are an important part of the forecasting process. Such comparisons not only provide a check on results, but where a significant difference in results occurs, valuable insight into the economy is gained by accounting for the difference.

B. Components of Model

1. Externally-Oriented Industry Employment Forecast (E_{xf})

Expansion in each significant component of this category will be forecast and the resulting employment computed, taking into account possible changes in productivity of workers or changes in the work week. The forecasts of resource-based industries will recognize the limits imposed by the extent of the resource. Similarly, the forecasts of market-oriented industries will recognize the limits imposed by marketing areas. Forecasts of other non-resource-oriented industries will be mainly based on national trends. The major industrial categories to be considered are:

Mining
Agriculture
Fisheries
Forest Activities
Manufacturing (by major classification).

Also to be considered in this category are those activities generally thought of as internally-oriented, but which actually are based to a significant degree on external influences. Examples would be tourist facilities or transportation facilities which would serve a much larger area than the local industry or market would justify.

2. Internally-Oriented Industry Employment Forecast (E_{if})

Employment in these industries will be computed by multiplying the externally-oriented industry employment (E_{xf}) by K_1, the ratio of internally-oriented industry workers per externally-oriented industry worker. This ratio would be adjusted to reflect the nature of the study area and the growth of this ratio over time.

4. **Total Employment Forecast** (E_{tf})

The forecast of total employment is the sum of the forecasts of each category of employment. This can be expressed as:

$$E_{tf} = E_{xf} + E_{if} \quad \text{or} \quad E_{tf} = E_{xf}\ (1 + K_1)$$

5. **Population Forecast**

The population is computed by multiplying total employment by K_2, the ratio of the number of persons in the population per employee. This ratio would be adjusted to reflect such trends as a growing number of households with more than one person employed. The number of households and dwelling units would be forecast from the population, recognizing the trends in family size, etc.

The model for the population forecast would be expressed as follows:

$$P = (K_2)\ (E_{tf}) \quad \text{or} \quad P = K_2\ (E_{xf})\ (1 + K_1)$$

APPENDIX II

Bibliography of Selected References on Economic Base Studies and Data Sources.

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PROJECTIONS OF THE LABOR FORCE IN THE UNITED STATES 1955 to 1975. Gertrude Bancroft, Bureau of the Census, Washington, D. C. October 1956.

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Western Regional Report #6, U. S. Department of Labor, Bureau of Labor Statistics, San Francisco, California. August 1959.

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Harold M. Levinson and supplementary technical material to the staff report of George W. Bleile and Thomas A. Wilson. Prepared in connection with the Study of Employment, Growth, and Price Levels, Joint Economic Committee, 86th Congress. January 30, 1960.

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PRICES, COSTS AND OUTPUT FOR THE POSTWAR DECADE: 1947-1957.
Charles L. Schultze, Committee for Economic Development. Library of Congress Catalog Card Number: 60-8582.

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NOTES

$$\frac{1}{\cancel{1.16c}\;.88} \times \frac{\cancel{3}}{4} = \frac{1}{3.52} = \frac{3}{10.56}$$

FLANNERY - ALL STUDIED ARE BASED ON MODELS -
~~SOME~~ SOMETIMES THEY ARE NOT STATED - BUT ONE IS ESSETIAL TO
ORDERLY ANALYSIS

TO WHAT EXTENT COULD BOD REMOVAL BE IN THE FUTURE?

UNEMPLOYMENT AND RETIRED WOULD BE SHOWN
IN THE INTERNALLY & EXTERNALLY - ORIENTED.

* INDUSTRY'S WATER USE WILL BE BASED ON WATER
COST - NOT ON PRODUCT QUANTITY

LOCATION FACTORS

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Introduction

Industry in the United States is moving. Due to the competitive nature of our enterprise system, a careful analysis must be made by any manufacturing establishment before a new location is selected. In making this analysis many factors must be evaluated, particularly those that vary significantly from area to area. The objective is the determination of that area in which the product can be manufactured and delivered to market at the lowest total cost.

There are many location factors to be considered in choosing a location for an industrial plant. The factors may be classified as (A) essential, (B) important, or (C) to be considered. The distinction between these categories is important. Essential requirements are those necessary if the plant is to operate profitably. Important factors are those which will increase the margin of profit but do not have the significance of the first category. Factors to be considered add to the attractiveness of the site and may have some bearing on profits.

There are 18 or more plant location factors recognized by authorities in the field to be analyzed in choosing a location for an industrial plant.

Arranged in alphabetical order these are:

- Buildings
- Climate
- Distribution Facilities
- Financial Help
- Fuel
- Labor
- Laws and Regulations
- Living Conditions
- Market
- Power
- Raw Materials
- Services (Equipment and Maintenance)
- Site
- Supplies
- Taxes
- Transportation
- Waste Disposal
- Water

The general locality is selected on the basis of the essential and important requirements to an industry, such as the availability of raw materials, markets and transportation facilities. Essentiality and importance will vary from one industry to another. "Factors to be considered" may help to determine the specific community within this general area. For example, pleasant living conditions are an advantage in locating most concerns. An agreeable climate and recreational facilities are helpful in obtaining high-class personnel. Some communities may have high land values and taxes, local ordinances, or community attitudes which would discourage industry. Other communities may offer inducements such as free or low-cost land, lower taxes, and financial grants.

Before a building site is selected, an engineering study should be made. This consists of a terrain study, including analysis of structural foundations and drainage conditions. In regard to water supply, the ground and surface water should be determined and the quality established.

Though it is hazardous to generalize on the locational economic factors of industries comprising broad categories, nevertheless, the following attributes may be accepted as characteristic.

This report will discuss locational factors of the following industrial categories which have heavy water requirements: (1) pulp and paper; (2) petroleum refining; (3) chemicals; and (4) iron and steel. Each is examined individually to determine its particular site requirements.

A study of the Texas Engineering Experiment Station illustrates the application of locational factors by the first three of the above-mentioned industries. This study is reviewed in the final portion of this paper.

Pulp and Paper Industry

The pulp and paper category is one of the largest and fastest growing industries in the United States. In the four-year span, 1954-1958, value of shipments increased from $3,769,700,000 to $4,769,772,000, or approximately 21 per cent.1/ The United States per capita paper consumption increased from 58.0 pounds in 1899 to 200.6 pounds in 1930, to 328.5 pounds in 1950, and to 421.0 pounds in 1955.1/

Pulp and paper mills are located in the New England-New York area, the Southeastern States, the West Coast and the Lake States. Essential factors governing the location of these mills are the availability of fibrous raw materials, an abundant supply of good water, good transportation facilities, ample power supply or sources of power, and waste disposal capability. Important factors are proximity to markets and an adequate labor supply. Factors to be considered are general living conditions, local ordinances, taxes, and the attitude of local authorities and the community.

Essential Requirements

The most important of all the factors listed is the availability of fibrous raw materials. Before the introduction of wood pulp, paper manufacturers used straw for wrapping paper, board and some printing papers, and rags for writing papers. In 1880, of a total of 619,682 tons of raw materials, approximately 40 per cent was straw; 29 per cent, rags; 16 per cent, old paper; and

15 per cent, manila stock. Rags were obtained from American cities which also supplied the markets for finished products; thus, Massachusetts, New York, Pennsylvania and Connecticut, in that order, led in the production of paper.[1/]

When wood pulp came into use, the industry spread farther into the New England states, which were richly endowed with spruce and fir. As these supplies became depleted, however, the wood pulp output shifted westward and southward.

The South is becoming increasingly important to the pulp and paper industry and contains 40 to 45 per cent of the commercial timber of the nation.[1/] The southern pine grows to the optimum height in 25 or 35 years, which is two or three times the rate of most northern species. It has very few limbs and knots, and extremely long fibers, which make it desirable. The development of the sulfate (kraft) process made the southern pine more usable for strong paper.

Until the late 1930's, attempts to use the southern pine for newsprint were unsuccessful. Grinding stones were easily fouled; high resin and pitch content fouled machines; and paper was marred by stains, holes and slime spots. However, adaptations were made in grinding stones, while chemicals solved the problems of "blue stain" (a fungus), slime, pitch and resin. Despite this, newsprint production did not move south until the weak price situation of the depression years was corrected. Even then, first attempts were financed in part by newspaper publishers and in part by the Reconstruction Finance Corporation.

Although much of the Nation's paperboard is made of waste paper, an increasing share in recent years has come from the kraft process. For any given strength, kraft is extremely light and, for any given weight, it is extremely strong. In 1925, only 20,700 tons of kraft paperboard were produced (0.7 per cent of the total); in 1956, the figure had risen to 5,971,000 tons (41.6 per cent of the total).[1]

The following figures on total wood pulp capacity show that the increases in output in the South are greater than elsewhere, although production in other areas has not declined.

Wood Pulp Production [1]

(Thousands of Tons)

Year	New England	Middle Atlantic	Lake	West	South	Total
1946	1,592	1,039	1,726	2,058	5,715	12,130
1947	1,605	1,143	1,842	2,175	6,024	12,789
1951	1,818	1,259	2,230	3,140	9,221	17,668
1952	1,910	1,316	2,316	3,303	9,928	18,771
1956	2,183	1,364	2,608	4,470	13,026	23,650
1957	2,197	1,531	2,658	4,654	13,891	24,931
1958	2,260	1,531	2,680	4,825	15,102	26,398

Throughout the pulp process, pulp is handled in water suspensions varying in consistency from 0.5 to 30 per cent solids, which means about 3 to 200 times as much water (by weight) as pulp.[2] The suspension fed to the forming part of the machine usually contains one-half pound of pulp to 99.5 pounds of water. Water is recirculated and reused whenever possible, in order to recover all the raw material (fibers) in suspension, but the over-all consumption may be anywhere from 25,000 to 100,000 gallons per ton of finished paper.[3] The amount is dependent upon the type of paper produced and the process used.

The water should be clean, of good color (if white papers are being made), low in chlorides and free of excessive amounts of dissolved solids. The supply must be adequate the year round. Most mills rely on surface streams or lakes, but some obtain their water from wells. Approximately 78 per cent of all pulp and paper mills use surface water and 22 per cent use ground water.[4]

In the North, streams have been used for carrying raw materials to the pulp and paper mills. Today, this method has been replaced by trucks or rail, as many mills find it necessary to go greater distances for their supply. In the South, rail and trucks are commonly used for transporting the raw materials. The reason why streams are not used is an interesting one - the southern pine pulp wood is too heavy and sinks in water.

Barges carry a sizable proportion of raw materials and finished products. Most of the larger mills are located on navigable waterways (e.g., Champion's Pasadena, Texas, mill on the Houston Ship Canal; Bowaters Southern at the confluence of the Hiwassee and Tennessee Rivers; Rome Kraft and Coosa River on the Coosa-Alabama River system; Union Bag Camp on the Savannah; Macon Kraft on the Ocmulgee).[1]

Pulp and paper mills depend heavily on transportation facilities. For efficient operation, replacement machine parts must be delivered quickly. In this case the time element is extremely vital. Therefore, the highway net and rail connections are significant.

Fuel for power generation is an essential factor to the pulp and paper industry. Many mills have their own turbines or generators to supply all or part of the power needed. In fact, the industry ranks first among all industries in generating power for its own use and seventh as a purchaser of power, and is in third place (outranked only by chemicals and by iron and steel) as a consumer of industrial power.[1]

Chemical recovery is high in the paper industry. At present, recovery systems are especially effective at the digester area, averaging around 90 per cent. However, the waste disposal problem continues to be enormous and must be solved if the industry is to grow. On several occasions, accidental releases of cooking liquors have resulted in fish "kills" in receiving streams.[1]

Color is the most objectionable characteristic of most paper mill wastes. To date no economically feasible method has been developed to remove color from the large volumes of wash water which constitute the major portion of wastes from this industry. Satisfactory disposal of these wastes can only be accomplished by dilution with color-free water, which means that pulp mills must locate near rivers and streams with sufficiently large flows to accept and dilute the colored wastes to a point that they present no further problem. The number of mill sites with water flows adequate to provide satisfactory dilution of treated wastes is becoming scarce.

Important Factors

Proximity to market is an important factor, simply because paper and paper products are low-value-per-ton products on which freight rates are quite high. The general rule is that plants tend to locate where total transfer costs of moving raw materials and products to market are lowest. Companies depending on waste paper as a raw material have no problem in this respect, since the source of supply and market are usually in the same general area.

An adequate labor supply is necessary to the industry, but is not generally a problem. In pulp mills the number of workers per unit of product is comparatively low and few skilled workers are required. When the announcement was made that the Bowaters mill was to be built in Calhoun, Tennessee, in 1953, people from 200 miles away sent in applications. With about 800 jobs available, the industrial relations manager received some 20,000 applications.[1]

Factors to be Considered

Factors to be considered are general living conditions, local ordinances, taxes and the attitude of the community and the local authorities.

Petroleum Refining

In 1957, the petroleum industry produced an average of 7,169,000 barrels of crude oil daily.[5] The per capita consumption of petroleum in the United States has increased from 7.5 barrels in 1929 to 10.1 barrels in 1939, to 14.1 barrels in 1950, and to 20.1 barrels in 1960.[5] The following table shows that the contribution of petroleum to the total energy consumed (as compared to other energy sources such as coal, natural gas, and water power) has increased spectacularly, especially between 1917 and 1927.

Energy Sources in the United States [5,6]
(In Per Cent of Total Consumption - BTU Basis)

	1917	1927	1937	1947	1957
Coal	82.8	67.1	54.0	50.7	*
Petroleum	9.8	23.8	32.7	33.7	40.5
Natural Gas	4.0	5.8	9.7	11.6	*
Water Power	3.4	3.3	3.6	4.0	*

* Data unavailable

Petroleum refineries are generally located at or near producing wells, at trans-shipment points or in areas of heavy consumption. Essential requirements are markets, transportation, availability of raw materials, water, and waste disposal capabilities. Important requirements are fuel and power, and sites. Factors to be considered are living conditions, laws and taxes.

Essential Requirements

There is a slight tendency to erect new refineries where markets are assured, due to the growing dependence on crude imports. The vast system of pipelines for transporting crude oils has facilitated the market location as evidenced by petroleum refining districts on the Great Lakes between Chicago and Cleveland, and on the Atlantic Coast between Baltimore and New York, rather than near the major oil fields.

Transportation costs of crude oil and refined products play an important part in the profitability of refining operations. Crude oil is transported from the oil fields to the refineries by pipelines, tankers, tank cars or trucks. Normally the cheapest mode is by oil tanker; it costs two and one-half cents to transport one barrel of crude oil 100 miles.[17/] Consequently, many refineries have located in coastal areas accessible to tanker transportation for movements of either crude oil or finished products, including foreign imports.

About 75 per cent of the crude oil received at refineries is transported by pipeline at some time. In 1958, the United States had a pipeline network in excess of 160,000 miles serving the petroleum industry. Costs of overland transportation by pipeline vary, but generally they average about three cents or more per barrel of crude oil per hundred miles.[8/]

Rail and truck facilities are not competitive with tankers or pipelines. These forms are used to a limited extent in new fields where no pipelines are available or in small fields where production volumes do not justify pipeline construction.

Petroleum refineries in the past have often located near major oil fields. Although some refineries may still do so, it is becoming less common, since it becomes uneconomical when production falls off at any single field.

An adequate water supply is essential to the location of a petroleum refinery. The conversion of gases into products requires from 0.8 to 44.5 gallons of water for each gallon of crude oil processed. Since the breaking up of crude oil into its products is a conversion of high thermal efficiency, almost 97 per cent of the water is used for cooling.[3]

Adequate waste disposal facilities are a necessity. During the processing of the crude oil, the effluent is run through settling ponds or tanks to collect waste oil and avoid pollution. If the effluent has accumulated harmful chemicals, it may also be treated to eliminate them. If the water supply is limited, water may be retained and cooled in ponds or towers for reuse.

Important Factors

The rates of electrical power may be significant. A refinery requiring a great amount of power may find it more economical to build its own power plant than to purchase utility company power.

Refinery equipment is extremely large and heavy. Therefore, it is very important that the soil in any selected location be able to support exceptionally heavy loads.

Factors to be Considered

Factors to be considered are living conditions, laws and taxes.

Chemical Industry

The importance of the chemical industry can best be illustrated by the increasing value of sales of chemical and allied products from 1939 to 1958.[9] In 1939 the sales were $4,339,000,000 and increased at a steady rate to $23,219,000,000 in 1958. The value added by manufacture from 1939 to 1957 increased from $1,818,941,000 to $12,116,000,000. The dynamic growth of this industry has always been one of its outstanding features.[9]

The chemical industry is broken up into two branches, organic and inorganic. Organic chemicals are defined as compounds which, like plant and animal matter, contain the very prevalent carbon atom. These are derived from residues of prehistoric life, such as coal, petroleum and natural gas, or from the present day materials of life, such as agricultural products. More than 2,500 chemical products come from petroleum and natural gas alone. Chemicals from these two products accounted for around 57 per cent of the dollar value of all U.S. chemicals in 1959. More than half of them ended up in such products as fibers, plastics, fertilizers, elastomers and synthetic rubber. The organic chemicals account for the largest number of the industry's products.[9]

Compounds that do not contain the carbon atom, but are obtained from such things as atmospheric gases, water and minerals, are inorganic compounds. For example, salt is used to produce chlorine, caustic soda, bleaches and soda ash; sulfur is used for sulfuric acid; and nitrogen and oxygen are used for ammonia, nitric acid and oxygen production.

In general, location factors follow the same pattern for all companies producing basic chemcials. For the purpose of this report the two divisions will be treated as one unit, with greater emphasis on the petrochemical industry.

The geographic location of a chemical plant depends largely on the essential factors: availability of raw materials; low-cost fuel and power; inexpensive transportation facilities; proximity to markets; water and waste disposal capabilities; and the availability of good quality labor. An important factor is proximity to other supplies and maintenance service. Factors to be considered are regulatory laws and practices, taxes, and living conditions.

Essential Requirements

Chemical manufacturers use a variety of raw materials, such as coal, petroleum, air, water and minerals. The minerals include such materials as sulfur, salts, sand, clay, lead, zinc, copper, iron, boron and aluminum. Plants which require sea water must naturally locate on the coast. The abundance of coal makes the West Virginia-Pennsylvania area particularly desirable for some organic chemical producers, while the abundance of petroleum makes the Gulf Coast extremely desirable for the petrochemical industry. Sulfur is obtained from underground deposits in Texas and Louisiana; salt from brine wells and mines in Michigan, New York, Ohio, Louisiana and Texas, as well as from solar evaporation of sea water in California and from Great Salt Lake, Utah; phosphate rock from Florida, Tennessee and the Rocky Mountains; and potash from New Mexico, California and Utah. The following list of the top ten states in chemical construction illustrates the importance of the availability of raw materials to the petrochemical industry.

TOP TEN STATES IN CHEMICAL CONSTRUCTION
(1958 MCA Construction Survey)

	(In Thousands)
Texas	$662,323
Louisiana	473,200
California	144,710
Tennessee	142,576
West Virginia	136,650
Ohio	134,900
Pennsylvania	127,190
New Jersey	117,114
Illinois	114,850
Florida	113,625

The availability of low-cost and abundant fuel and power is influential in locating a chemical plant. Many have located in certain areas where raw materials, such as coal, petroleum and natural gas are present, and these raw materials can also be used as inexpensive sources of fuel and power.

Low-cost transportation facilities are important to the chemical industry. The lack of inexpensive modes of transportation has hindered the establishment of chemical plants in some areas. The cost of transporting raw materials and the finished product must be compared when determining a suitable location. If the packaged product has a higher freight rate, it is probably more economical to locate near the market and ship raw materials.

In 1954 the chemical industry, one of the Nation's major water-using industries, used 24 per cent of the total industrial water intake, or 2,827 billion gallons.[3] The greater percentage of this water is used for cooling. To produce 100 pounds of ascorbic acid, for example, requires 85,000 gallons of water; to produce 100 pounds of bromine requires 250,000 gallons of water. This stresses the need for an adequate water supply in the selection of a chemical site.[2]

The number of suitable sites with good quality water supplies is decreasing, because in many instances municipal and industrial wastes receive inadequate treatment prior to discharge and cause serious degradation of receiving streams into which they are released. Since these streams are often the only source of water for potential industrial development downstream, the number of industries that can use the lower quality water is limited. Closer attention is being focused on this situation. More stringent laws are being passed and stricter enforcement of existing legislation is resulting in the improvement of conditions that have plagued entire river basins for decades. New industrial plants are active in the development of the most advanced equipment for pollution abatement or avoidance procedures. In some areas, strict waste disposal regulations are imposed on chemical plants. This is especially true on the Ohio River from Pittsburgh to Cincinnati; the Delaware River from Phillipsburg to the Delaware Bay; the Susquehanna River from Harrisburg to Chesapeake Bay; Lake Erie near Cleveland; and the Houston Ship Canal.

As in the petroleum industry, markets are becoming increasingly important. Nearness to markets and supplies are especially important if water transportation is unavailable.

Many skilled and technical workers are needed in the chemical industry. Of a total of 846,400 employees in May 1959, over 60 per cent are production workers, many of whom are highly skilled. Administrative, scientific, sales and executive positions make up the remainder. The largest part of the plant workers are process workers, who operate chemical and mechanical equipment. Because of the highly technical and varied nature of the industry's operations and products, it is often necessary for employees in administrative, purchasing, sales or legal capacities to have scientific or engineering backgrounds.9/

Important Factors

Nearness to supplies and maintenance services are important in selecting a location. The direction of prevailing winds, which may carry objectionable odors to the surrounding areas, must certainly be appraised in this type of operation.

Factors to be Considered

Factors to be considered include land values, local ordinances, zoning, homes for workers and community attitudes.

Iron and Steel Industry

The iron and steel industry in the United States is basic to the Nation's economy and to its standard of living. Spreading to all four corners of the country, steel producing facilities are located in 31 states. They are concentrated in Pennsylvania, Ohio, Indiana and Illinois, which have 27 per cent, 20 per cent, 12 per cent and 9 per cent of the Nation's output, respectively. The others have considerably less.2/

The essential requirements for this industry are the availability of raw materials, markets, transportation, water, fuel, waste disposal, and labor. Important requirements are maintenance and service facilities. Factors to be considered are living conditions, taxes, and local laws.

Essential Requirements

Of the essential requirements, the availability of raw materials, particularly ore, coal and limestone, has probably played the most important part in determining the steel-making centers of the United States.

For every ton of pig iron produced, three to four tons of raw materials are needed. High quality iron ore deposits are found in northern Minnesota and Michigan. The value of iron ore extraction in Minnesota ranged between $350,000,000 and $550,000,000 annually between 1951 and 1957.5/ In Michigan, the value ranged between $75,000,000 and $105,000,000 annually during the same period.5/ Ninety per cent of all the coal mined in the United States is mined in Pennsylvania, Ohio, Indiana, Illinois, Virginia, West Virginia and Kentucky. Rich limestone deposits are found in Michigan, Pennsylvania and Ohio. Because of the geographical separation of these areas, one or more of the raw materials must be transported by rail, water, or both. Since coal is lighter and takes up more room than iron ore, it is generally more economical to locate mills closer to the coal supplies than to the iron ore mines, even though the quantity of iron ore required in the process is greater than the coal. However, in some cases coal is moved to the ore, and in others both are moved to a junction point. Before the utilization of electric power in the industry, steel-making facilities also depended on the coal fields as a source of power.

Many steel plants, as previously mentioned, have concentrated in certain parts of Illinois, Indiana, Ohio, Pennsylvania, New York and West Virginia. The raw materials are relatively accessible from these areas, since the Great Lakes provide a convenient means of transportation.

The proximity of steel-producing centers to the market is another essential factor. A densely populated territory or a general industrial area is often a good location since scrap iron, which can be used as a raw material, and markets are both available. Plants located on the Atlantic Coast can readily receive foreign iron ore supplies from Venezuela and Labrador-Quebec and in turn can supply the Eastern market with steel and steel products.

The presence of raw materials and the nearness of markets have led to the establishment of steel mills in the Birmingham, Alabama, region. This area has substantial deposits of iron ore, coal and limestone, which are closer together than in any other area of the United States. Lone Star Steel located in Dangerfield, Texas, because this area has deposits of iron ore and limestone and transports coal from nearby Oklahoma. Located in one of the richest oil fields in the world, Lone Star produces iron casings, drills and other related products to supply the available market.10/

Economical transportation is an essential requirement to this industry. Its raw materials, and most of its products, have a low unit value in proportion to their weight. Without low-cost convenient transportation, production costs would rise enormously and make steel a less economical product.

The industry transports its finished product by rail, truck or water. Water transportation, however, is used whenever possible, as it is most economical.

Water is extremely important to the iron and steel industry. It is used in a number of ways, particularly for cooling blast furnaces. A furnace with a capacity of 1,000 tons of iron a day uses from 1,400 to 65,000 gallons of water in 24 hours.3/ Approximately 80 per cent of the water used is reused, and only leakage and evaporation losses of some 15 per cent must be made up.2/

Most types of fuel, including coal, coke, gases, fuel oil, natural gas and electricity, are used in steel production. However, within the last ten years the industry has become one of the country's top consumers of electricity.

Stream pollution arising from the extensive operations of the iron and steel industries has produced a need for adequate waste disposal capabilities. The most objectionable characteristic of the wastes is the suspended solids, which are mainly particles of ore and coke. Some of these solids settle readily and form a coating on the bottom of the lake or river. These deposits are destructive to bottom organisms which are an important source of fish foods. The suspended solids also add a deep gray or black appearance to the water, making it unsatisfactory for recreational uses and aesthetic conditions.11/

Phenols and cyanides may also be present in the wastes. These chemicals not only are toxic to aquatic life, but can be a menace to public water supplies and bathing facilities. Therefore, a suitable means for disposing of waste water from iron and steel mills is a necessity.11/

Steel mills require the service of men skilled not only in steel-making processes, but in many other lines. About 1,200 separate and distinct jobs are to be found in the plants and offices of the iron and steel industries.2/

Important Factors

Maintenance and service facilities are important to this industry.

Factors to be Considered

Living conditions, taxes and local laws are factors to be considered.

Plant Location Factors in Texas

The significance of the many factors which influence the location of new plants, mills and factories in Texas has been brought out by the Texas Engineering Experiment Station in a report entitled An Evaluation of Plant Location Factors in Texas.

Questionnaires were sent to 850 manufacturers throughout the State. These manufacturers were to indicate, in order of importance, the five basic reasons for the location of their establishments. Three hundred and fifty questionnaires were selected and classified according to the Standard Industrial Classification List into 14 groups. The industrial groups, number of returns in each group, and percentage of total in the State are shown below. Iron and steel firms were omitted in this survey.

	Industry Group	No. of Returns	Per Cent of Total in State
1.	Food & kindred products	38	3.5
2.	Textile mill products	10	17.2
3.	Apparel products	22	7.7
4.	Nonapparel textile products	8	12.9
5.	Lumber and wood products (except furniture)	22	3.3
6.	Furniture and fixtures	19	8.7
7.	Paper products	13	27.0
8.	Chemicals and allied products	41	15.1
9.	Petroleum products	11	11.7
10.	Rubber products	13	81.2
11.	Stone, glass and clay products	28	13.3
12.	Fabricated metals (except machinery and transportation equipment)	66	25.5
13.	Machinery (except electrical)	31	8.7
14.	Miscellaneous	28	21.2
	TOTAL	350	7.8

To obtain the relative weight, each locational factor was tabulated according to the position assigned it by the respondent firms. A factor in first position was given a value of five; those in following positions were given values of four, three, two and one, respectively.

Results of the survey are shown in the following figures by industrial categories.

The paper and paper products industries in Texas are primarily concerned with markets, and labor and distribution facilities. See Figure 1. Since the pulp industries are not considered, raw materials, transportation and water are rated lower than they would normally be in the pulp and paper industry.

The importance of raw materials, transportation and markets is revealed in the eleven returns of the petroleum products industry. See Figure 2.

The chemical industry has developed in Texas in recent years because of the availability of raw materials, presence of a growing market and good transportation facilities. See Figure 3.

It is apparent that when all industries of Texas are considered, market, labor and raw materials are the three most important location factors. Water is of minor importance in the location of an industry within this State. Waste disposal capabilities was not on the list of factors. See Figure 4.

CONCLUSIONS

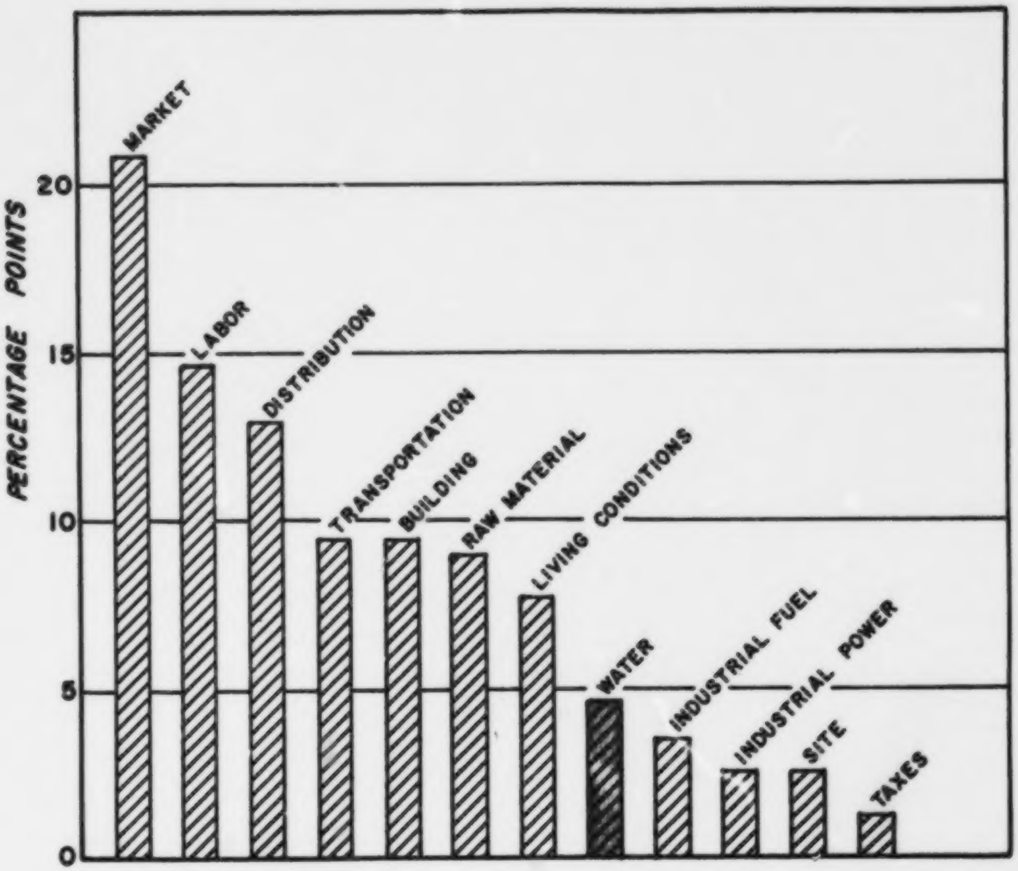
1. Economic theory of industrial location is based on the maximization of the investment situation as determined by the profit margin; that is, achievement of the widest spread possible between cost and income or revenue.

2. Seldom does one factor alone play the decisive part in determining a plant location. A combination of factors which will bring the greatest monetary returns will govern the choice of the site.

3. Heavy water-using industries are generally located near their source of raw materials, because their kind of process generally involves bulky and costly-to-move raw materials, as compared to the finished products.

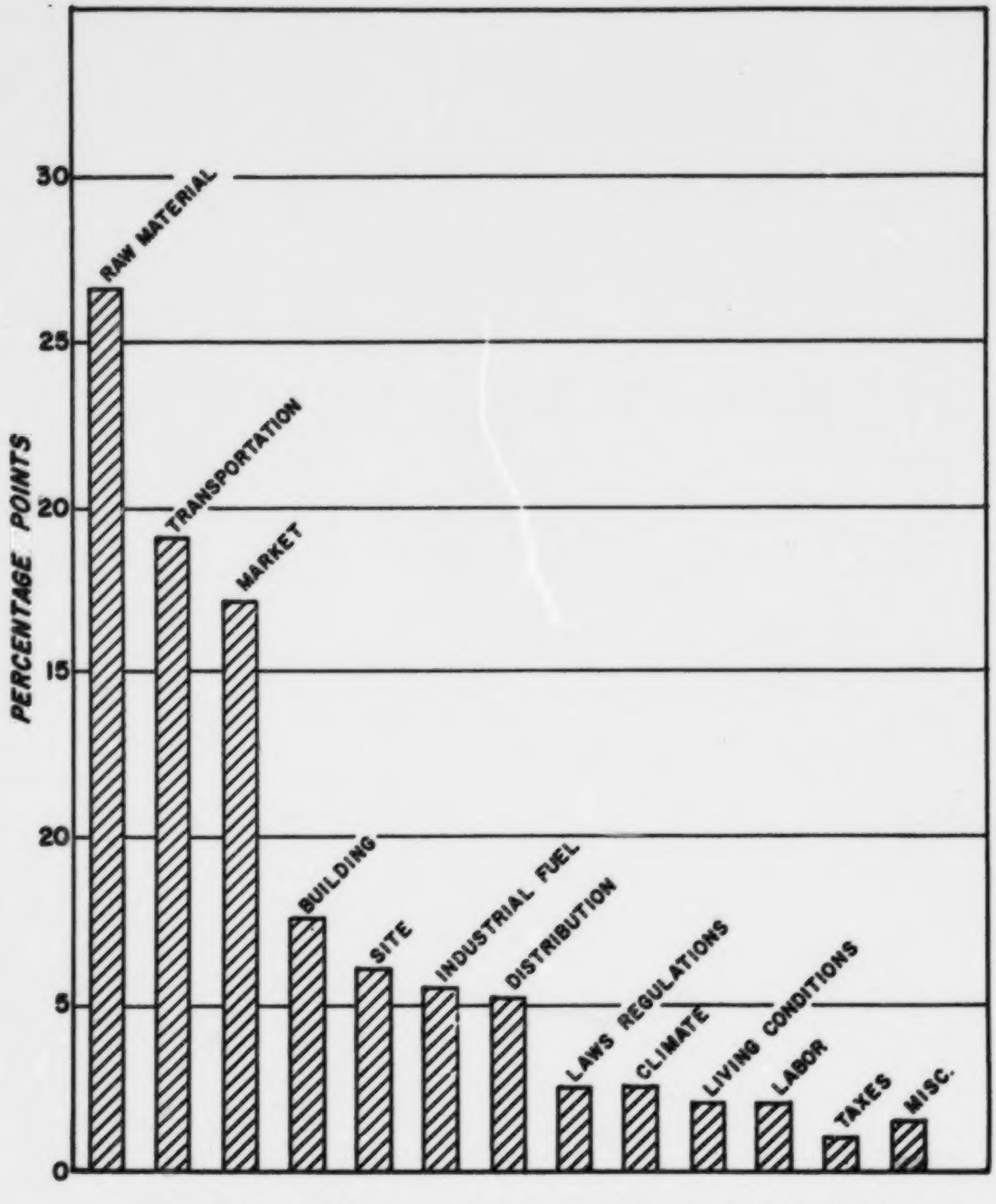
4. An adequate water supply is essential for all industries, but it is only when all other factors are equal among several locations that abundant and cheap water plays a decisive role in industrial location. Factors such as the availability of raw materials, proximity to markets and inexpensive transportation must be present in conjunction with the water or the site is infeasible.

5. Heavy water use means large volumes of liquid waste with attendant problems of satisfactory disposal. Sites with adequate waste disposal capabilities for the heavy water-using industries are becoming scarce. With strict regulations against pollution, the problem is still present. Therefore, waste disposal is a significant factor in locating an industry.



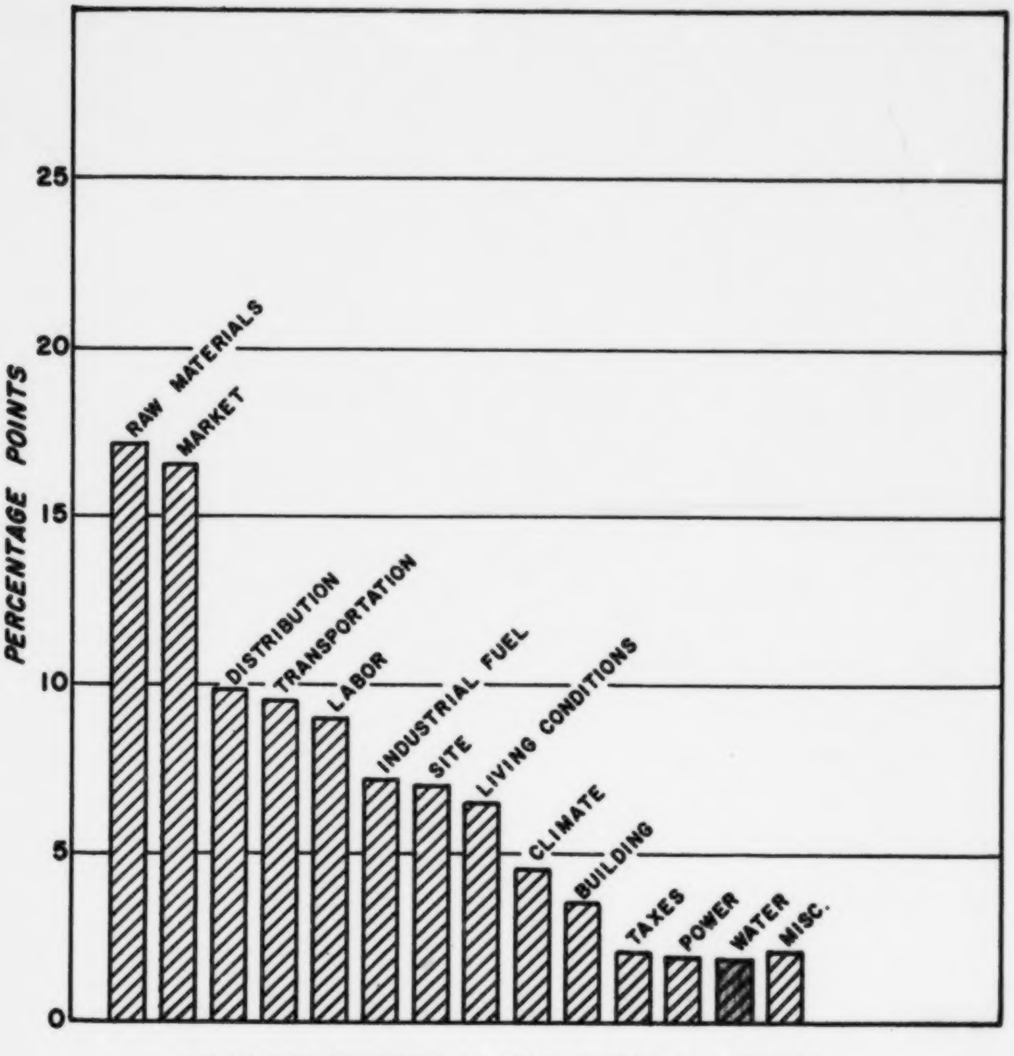
LOCATION FACTORS IN THE PAPER PRODUCTS INDUSTRY

FIGURE I



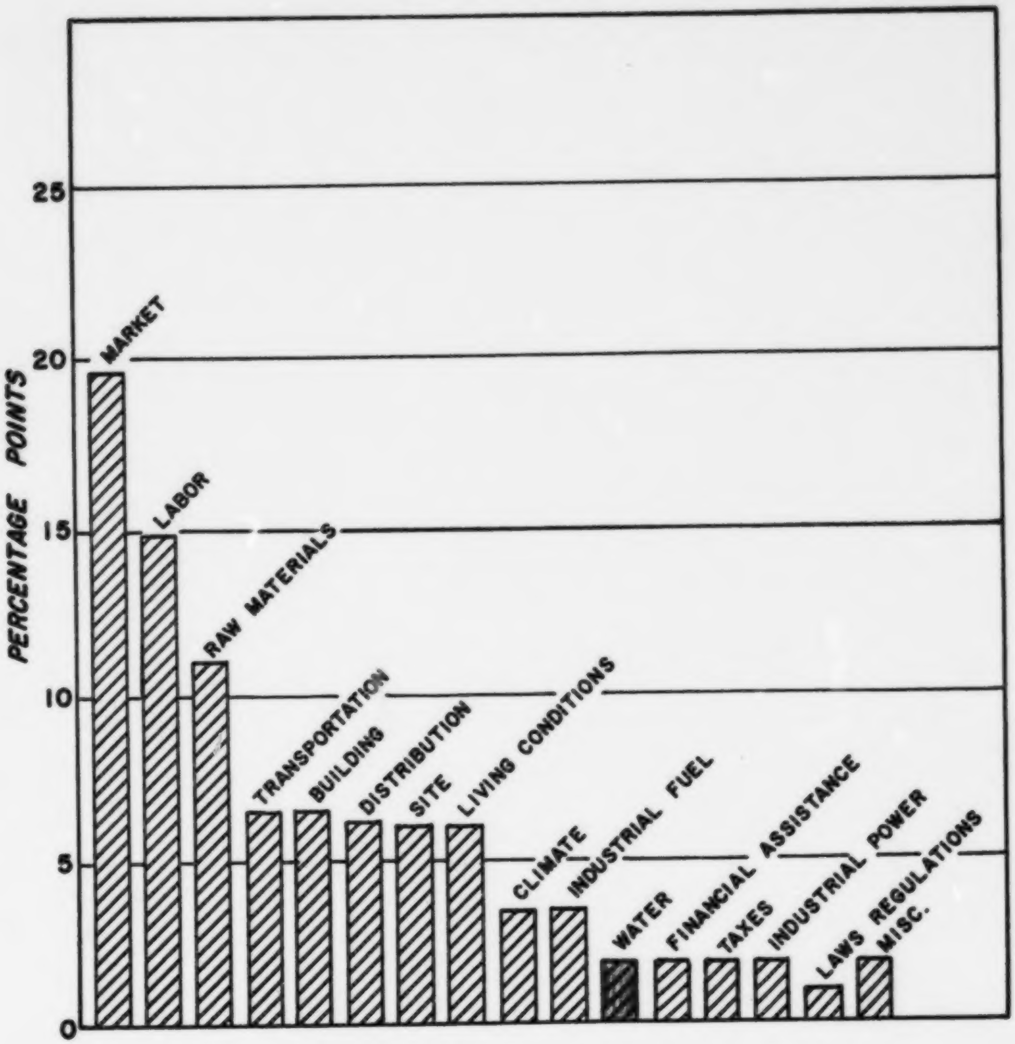
LOCATION FACTORS IN THE PETROLEUM PRODUCTS INDUSTRY

FIGURE 2



LOCATION FACTORS IN THE CHEMICAL INDUSTRY

FIGURE 3



LOCATION FACTORS IN TEXAS INDUSTRIES

FIGURE 4

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PROJECTING WATER REQUIREMENTS IN THE BOONDOCKS

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U. S. Department of Health, Education and Welfare

Much has been said about projections of growth and water requirements for the heavily populated, highly industrialized portions of our Nation - the SMAs (Standard Metropolitan Areas), while little emphasis has been given to the many small cities, towns, and villages outside of the SMAs. The intervening areas served by these less populous municipalities are, after all, the largest part of the Nation in terms of land area. Furthermore, approximately 38 per cent of our population lives and works outside of the 209 SMAs - out in the boondocks.

What method has been used in projecting population, manufacturing and water demand?

To date, projections for population have been founded upon growth trends established over the years, while industrial change has been predicated upon evaluation of manufacturing employment conditions. Water demands for the metropolitan areas can be and are projected through statistical analyses of population growth trends and employment patterns.

Why not apply this method for population, employment and manufacturing, and water demand projections of non-metropolitan areas?

In contrast to the metropolitan areas' steady growth, many small cities and towns have experienced sharp declines in population, even to going out of existence; while others have just stood still. In the latter case, it seems that every time someone comes to town, someone also leaves. Still, other areas grow and expand after many years of little change in population or industrial complexion. This situation with respect to the outlying areas limits the use of a statistical analysis method, since population trends are not clearly defined. Employment and manufacturing patterns seem to be almost as uninterpretable. Since many of our small towns have just recently gained industries, projections would have to be based upon only a smattering of data. The problem of sketchy municipal water use data is also a factor.

How much municipal water demand can be expected to develop for even the largest of the towns in the boondocks?

The municipal systems serving the major communities in the non-metropolitan areas seldom have an average (yearly) demand above 6 to 8 mgd (based on maximum population of 50,000).

This seems like a drop in the bucket compared to the projected Dallas-Tarrant County 2010 demand of 1502 mgd. Are there other significant factors?

Yes, one industry of the principal water using class can completely overshadow municipal water requirements for the area in which it is located. Further, these municipalities are, more often than not, located some distance from a major watercourse. This can create waste disposal problems, since large industrial water requirements may result in large quantities of industrial wastes without a suitable point of discharge. This aspect of water use is all too frequently overlooked.

If the statistic analysis and ratio of employment growth methods of population projection are not entirely applicable for the outlying area, what approach can be used?

Certainly, the population requires a means of livelihood. The industries which provide employment generally develop, prosper, and grow as a result of many factors. While these factors vary from one type of industry to another, most fall into one of three broad categories -- market oriented, labor oriented, or resource oriented. All of these major factors are essential to every industrial operation.

How do these affect development of outlying areas?

Since the outlying areas are by comparison to SMAs sparsely populated markets, most of the strictly market-oriented industries seem to locate in or near the big market centers, the SMAs. The second factor, labor, may or may not favor a particular region. But almost without exception, the metropolitan areas have a great advantage over the boondocks in supplying industries' demand for labor.

The third factor, resources, is the key to most of the projected municipal and industrial water requirements for the outlying areas. An inventory of an area's or region's resources will serve as a guide to future developments. These resources can be divided into two groups - depletive and non-depletive.

Depletive resources play an important role in a region's short-term (or even long-term, depending upon the reserves and operation) development though they may not noticeably affect water requirements. These resources are mined, i. e.,are not regenerative, and include petroleum, natural gas, natural-gas liquids, coal, sand and gravel to name only a few.

Non-depletive resources are found throughout our Nation and are renewable. These include soil, forests, climate (temperature, growing season, etc.), and water. Agriculture is the backbone of the outlying areas, providing an economic base for many small towns. As the local agricultural economy goes, so goes theirs.

An inventory of resources and existing utilization, population, and employment can be analyzed and correlated to establish future trends in production, employment, and water requirements.

Which resources can affect employment and population growth, and, more important, will require significant quantities of water for utilization?

It is generally true that when raw materials are perishable or bulky or have a high degree of weight loss in processing, the initial step of the manufacturing process is carried out close to the raw material source. There is no question that this factor is of major importance in projecting industrial development and expansion in outlying areas. There is hardly a major water using industry in the non-metropolitan area that is not directly based on local agriculture, forestry or mineral raw materials. The fact is, existence of and access to an abundance of perishable, bulky, or low yield raw materials not only have been basic to the growth of manufacturing in the boondocks, but will determine the direction of industrial development and to some degree its rate of growth.

While the extraction and manufacture of goods from raw materials are significant in projecting employment and population trends, they do not necessarily influence water requirements. There are, however, two industrial classifications which are heavy water users and have large segments which are invariably located outside of SMAs - Food and Beverage (20) and Pulp and Paper (26).

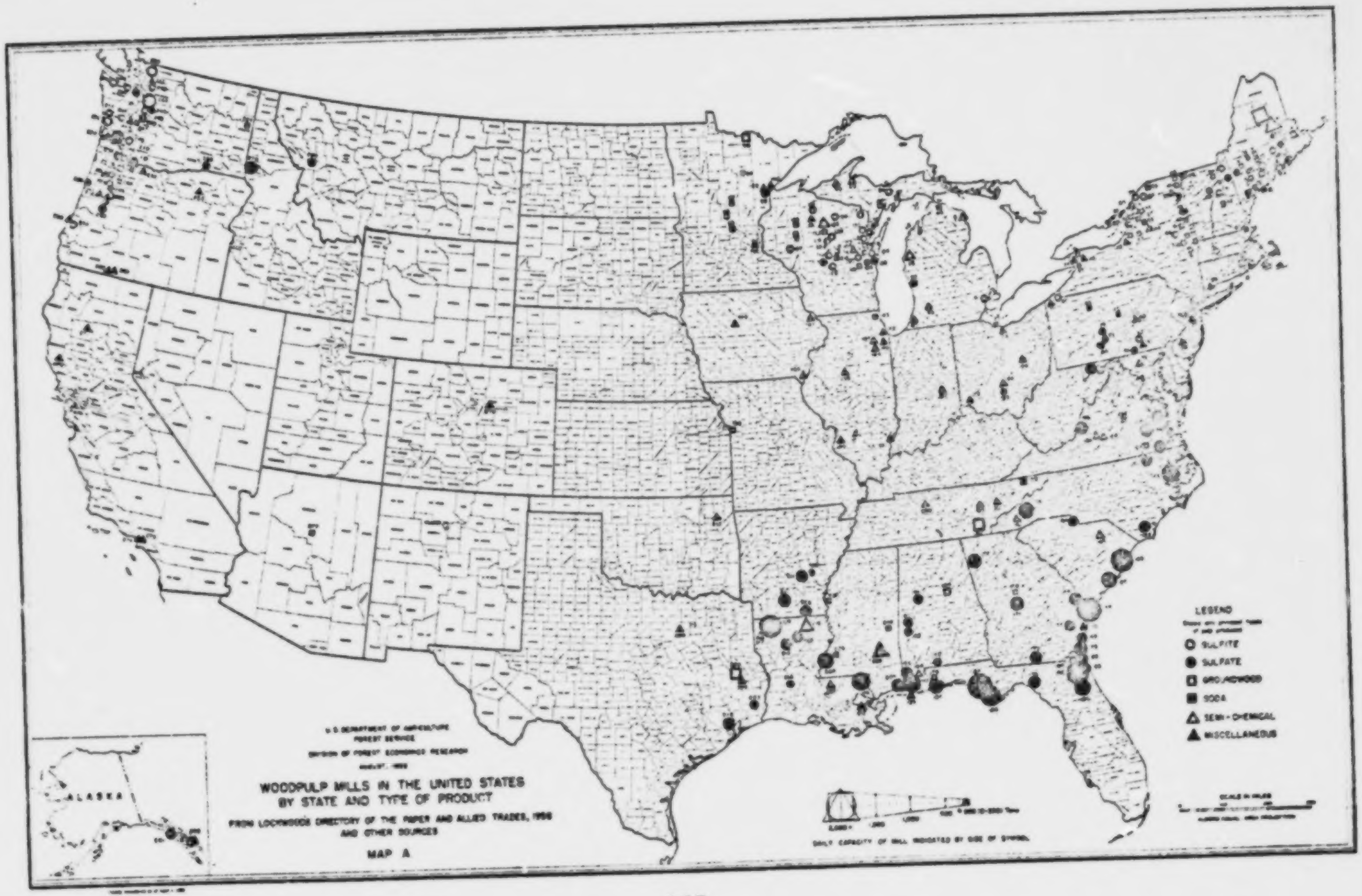
Considering the pulp and paper products category, first, (since pulp mills are found in all Public Health Service regions, see Map A) - where does water fit into this manufacturing process?

The largest part of this industry's water demand is associated directly with the production of wood pulp from bolts of cordwood. This substantial water use is further a part of the paper-making process. Once the paper is made, there is little water required for conversion of the paper (or paperboard) to cups, plates, boxes, bags, and the numerous useful items fabricated from paper.

Pulpwood is a resource which is both bulky and has quite a loss in the initial processing stage. Therefore, most pulp mills are located in or near forests. Since water is the conveying medium for paper making, the pulp is more often than not passed right on to a paper mill, see Figures 1 and 2. (When this is done it is called an integrated pulp and paper mill.)

How can regional production for this industry be projected?

The amount of pulp and paper production which an area will support is a function of yield from the forests in the region. For example, the forests of southern Arkansas with good management can produce about one cord per acre per year without depletion. This production rate is based on pine rather than hardwoods (which are slower growing). The kraft paper industry in the South is built and expanding on this resource. Presently, the yield in this area is but half of this amount since there is little or no management practiced on



U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
DIVISION OF FOREST ECONOMICS RESEARCH
AUGUST, [illegible]

WOODPULP MILLS IN THE UNITED STATES
BY STATE AND TYPE OF PRODUCT

FROM LOCKWOOD'S DIRECTORY OF THE PAPER AND ALLIED TRADES, 1956
AND OTHER SOURCES

MAP A

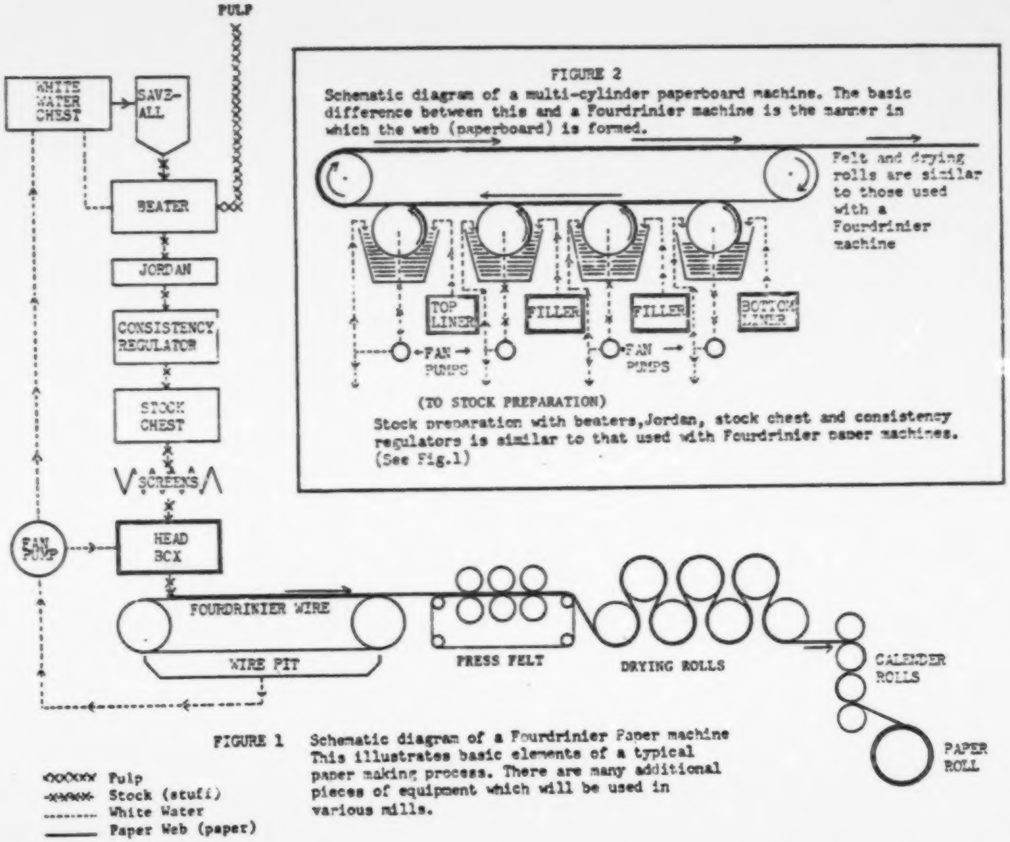


FIGURE 2

Schematic diagram of a multi-cylinder paperboard machine. The basic difference between this and a Fourdrinier machine is the manner in which the web (paperboard) is formed.

Stock preparation with beaters, Jordan, stock chest and consistency regulators is similar to that used with Fourdrinier paper machines. (See Fig.1)

FIGURE 1 Schematic diagram of a Fourdrinier Paper machine This illustrates basic elements of a typical paper making process. There are many additional pieces of equipment which will be used in various mills.

most of the acreage, in private ownership. However, reserves are being built and, as the market for pulpwood expands, expectations are that increased efficiency will materialize.

An additional factor in projecting pulp and paper production is the portion of the timber which will go into lumber and other wood products. Projection for lumber utilization (and employment) should be tied in with the pulp production projections. Currently, the split is about 50-50 in the forests of Region VII. Since the type of timber and complexion of the forest products industry vary from region to region and even within a region, each project area should be studied and projected on its own merits. Cordwood production can then be converted to product output by determining the wood - product ratio. In southwestern Arkansas, the kraft process predominates with a present ratio of about 1.75 cords per ton of product.

Can these timber and production data be translated into water demand projections?

Water requirements for the pulp and paper industry's development can be projected on a gallons per ton of production basis. The predominant process used to produce pulp (and paper) from the type of pulpwood available in the area can be studied to provide the projected water requirement. Although the paper-making process is constantly being improved, there do not appear to be many ways of water saving beyond those now in use. The majority of the requirements are for conveying and washing the fiber stock. As the number of conveying steps and washings increases, so does the amount of water required. Groundwood pulp requires the least; soda pulp the most.

How do the water quality requirements for pulp and paper production compare to the Public Health Service drinking water standards?

Water quality requirements for pulp and paper production are more restrictive in many respects, particularly chlorides and other corrosive elements, iron, manganese, hardness, turbidity, and color content. Until recently, the mills in this region predominantly used ground water, but production expansion programs have resulted in switches to high quality surface supplies.

At this point, consideration must be given to the effect the waste loading from this industrial activity will have on the basin downstream. Will the wastes resulting from this use of water over-load the receiving stream's waste assimilating capacity even after 90 per cent of the B.O.D. has been removed?

Although the pulp and paper industry requires an extremely high quality of water for production, the wastes produced by its operations are perhaps the most difficult to handle in terms of quantity and pollutional characteristics. An average raw waste has a population equivalent of 300 per ton of production (50# B.O.D./ton). Although, each mill has a distinctive waste characteristic, a study of the region's paper making processes will provide an insight into projected waste production founded on the previously developed data. Return flows are usually on the order of 90 per cent of raw water requirements.

Much research has been conducted by the industry on these wastes and treatment methods have been developed with appropriate engineering guides. There is one characteristic, however, which at present defies economically feasible removal from kraft wastes - color. The level of concentration for this characteristic of kraft waste varies upward from 250 color units. This color is derived from the extraction of lignins and tannins (in the pulping process) and is chemically similar to swamp drainage. This color rules out most municipal and industrial reuse (except cooling water) at this level, and is aesthetically objectionable. Since biological waste treatment will not reduce color, the receiving stream must provide enough dilution to reduce the color to a reasonable level (say 50 to 75). Thus, the waste disposal aspect of pulp and paper making may be more of a controlling factor than water supply.

As the result of research by the pulp and paper industry several processes for removal of color from kraft mill effluent have been developed and tested in pilot plants. All were found to have serious drawbacks. Presently a color removal process incorporated in the causticizing flow sheet, based upon lime recovery, is being tested on a plant scale. Although reports indicate some bugs in the process, the feeling of those working with the process is that a solution to the color removal problem can be found.

Everything up to this point has turned on projected water requirements for production. Are there other uses for these data?

These projections can be related to employment and population projections for the region under consideration. Paper mill towns in the boondocks have, to date, tended to be dominated by this one industry. Often related operations take root adjacent to the mill, but these do not exert a significant water demand although providing employment. The employment to population ratio can be established and projections made accordingly.

In this way, timber resources, product demand, production, industrial water requirements, employment, municipal population, municipal water requirements, and waste loadings can be tied together, compared with national and regional factors, and projected as required.

We are all aware that these figures will not make these projections work out in themselves, but they appear to be the controlling factors in development of this industry with its associated employment and effect on population in outlying areas to date.

The other industrial segment which can have a great impact on water requirements in the outlying areas is classified under food and beverages - more particularly food processing and canning.

What role does water play in the canning and food processing industry?

This industry's operation is similar to that of the pulp and paper industry. The majority of the water requirements are for conveying and washing of the raw materials and product - fruits and vegetables. The operation is seasonal, but large quantities are required during this relatively short time.

On what basis can water requirements be projected?

The approach for projecting production, employment, etc. can parallel that of the pulp and paper industry. Projections can be founded on productivity of the soil and type of crop best suited to local conditions. The production and employment pattern for the agricultural industry will be discussed by Bill Eichberger. Projected product demands and production figures can be converted to area output in tons or cases or some other convenient unit of measure. While we do not have much data on water requirements, we do have data on waste quantities. Approximately 95 per cent of the water requirement in this industry is released as waste. Table 1 illustrates typical quantities and characteristics encountered. Local conditions may indicate variation from these amounts. As with pulp and paper, employment can be tied to output and projected accordingly. However, this employment pattern is complicated by the fact that this industry is seasonal and will probably not support as much service - related employment, and population per employee as pulp and paper. Details will vary somewhat with locale, however, projections can be made on this basis.

TABLE 1. VOLUME AND CHARACTERISTICS OF CANNERY WASTES

(From Rudolf's Industrial Wastes)

Product	Volume Per Case (Gals)	5-Day BOD (ppm)	Suspended Solids (ppm)
Apples, sauce		1,685-3,453	
Apricots	57-80	200-1,020	260
Asparagus	70	100	30
Beans, green or wax	26-44	160-600	60-85
Beans, lima	50-257	189-450	422
Beans, baked	35	925-1,440	225
Beets	27-65	1,580-5,480	740-2,188
Carrots	23	520-3,030	1,830
Corn, cream style	24	623	302
Corn, whole kernel	25-70	1,123-6,025	300-4,000
Cherries, sour	12-40	700-2,100	20-605
Grapefruit	5-56	310-2,000	170-287
Mushrooms	6,600*	76-390	50-242
Peaches	1,300-2,600*	1,350	600
Pears	1,300*	2,250-4,700	1,200-6,700
Peas	14-56	380-4,700	272-400
Potatoes, sweet	3,500*	295	610
Potatoes, white		200-2,900	990-1,180
Pumpkin	20-42	2,850-6,875	785-3,500
Sauerkraut	3	6,300	630
Spinach	160	280-730	90-580
Tomatoes, whole	3-15	570-4,000	190-2,000
Tomatoes, juice or products	38-100	178-3,880	170-1,168

* per ton

Is the food processing industry's waste disposal situation also like that of the pulp and paper industry?

Waste disposal for the canning industry poses a different sort of problem than that encountered in pulp and paper industry projections. In most cases, water use and waste production are seasonal with low stream flows and high waste production coinciding. Waste treatment methods have been worked out. However, due to the concentration and quantity of the wastes produced, careful analysis of the ratio of waste flow to stream flow are in order if stream quality is to be maintained downstream from the demand centers.

Compilation of the data outlined will provide a basis for projecting water requirements in the boondocks. Special situations do exist; however, the general approach outlined here should provide a basis for projecting production, employment, water requirements and waste loads for those industries and areas. The technique explored here for a specific part of our work has been used in various forms with an array of parameters for many years in "Water Requirements Survey" work in the southwest.

Are there any problems associated with this approach to water requirement projections for the boondocks?

Although this technique will yield a fairly good projection of areal water requirements in the long run, it does not furnish a clue as to when and where this demand will develop. Pulp and paper water demands can go from nothing to 50 mgd with the construction of just one big mill or it could develop in medium sized increments. Local management may be able to furnish the answer; however, they are prone to keep long range plans to themselves for competitive reasons. A local management interview will not be possible when no mill now exists in the project study area having a projected potential.

In summary, on what bases can water requirements for an outlying area be projected?

There are 4 general steps which can be used to project water requirements for the boondocks --

(1) The area's resource inventory holds the key to its growth and development.

(2) The area's water using resource oriented industry (or industries) play a vital role in determining future water requirements. Pulp and paper production and food processing are outstanding examples of this type of industry. Water requirements can be projected directly for these industries.

(3) Employment and population patterns can be founded on the resource base for relatively remote communities. Municipal water demands can be projected proportionate to population to be served.

(4) Waste loadings to be released can be predicated on industrial water use and municipal water demand.

What one factor will have more effect on projected water requirements for the boondocks than any other?

Insofar as projections of water requirements for the boondocks are concerned, it would appear that, in Region VII, waste disposal (stream quality maintenance) will be more of a controlling factor than any other. How about your area?

NOTES

NEED FOR NATIONAL PROJECTION ON GROWTH
WITH SELECTED SITES BY REGIONS.

by Dr. Willis G. Eichberger, Economist,
Water Supply and Pollution Control,
Public Health Service, Region IV

AGRICULTURE - EFFECTS ON WATER DEMANDS

INTRODUCTION

As long as water is in abundant supply to meet the demands of all water uses or purposes, demand for water presents no problem. It is only when supply is small relative to demand, so that competitive alternatives exist, that concern over use of water occurs. In many, and probably most, parts of the United States today water supplied to meet demands of all legitimate water uses are limited either quantitatively or qualitatively. Because of these limitations on water supplies and because of increasing demands for goods and services produced by water resources, we must consider the possibility of obtaining the greatest possible benefit from our water resource supplies.

In any given area water use is rarely, if ever, confined to a single purpose. It is used for human consumption and other necessities of human livelihood, animal consumption, industrial production, power production, waste disposal, navigation, irrigation, recreation, fish and wildlife habitat, and many other uses too numerous to mention here. Any or all of these uses present no problem as long as the quantity and quality of water required for each purpose is sufficient to meet the demand. It is only when quantitative or qualitative restraints are placed on the supply that choices must be made between alternative uses. When limitations become operative it becomes necessary to establish criteria to specify efficient use of the diminishing supply. These criteria should serve as the basic framework, consistent with needs, laws, and policies, for modifying physical means of water use. In the field of water resource investigations inquiry should be focused initially on water supply, total demand for water, value of water for particular uses from the public point of view, and costs (private and public) of particular uses. Finally, efficient allocation of scarce water supplies between competing uses should be based on the principle of maximization of economic welfare. Before we can deal intelligently with the problem of efficient allocation of our water supplies among the various competing uses of water, it is necessary to make educated guesses as to the future demand of each alternative use.

Agriculture is the largest single water user of any industry in the United States. In 1955, eleven western states supported about 25.5 million people. These states withdrew about 104 billion gallons of water per day from surface and underground supplies. In the same year, the eleven most populous eastern states supported about 78.5 million people. These states withdrew about 68.5 billion gallons of water per day. Thus the eleven western states used 4,112 gallons per capita per day as compared to 872 gallons per capita per day for the eastern states. This difference in per capita use is attributable almost entirely to irrigation requirements.[1/]

PROJECTING FUTURE REQUIREMENTS

Because our water resources investigations must necessarily be concerned with the future, it is necessary to make estimates or projections of future demands for water for agricultural uses. These demands will be determined by farm population, numbers and kinds of livestock on farms, and the acreage and kinds of crops expected to be grown. In the arid west and in those parts of the humid east where rainfall is improperly distributed seasonally for optimum crop production, irrigation will be a big factor in

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1/ Irving K. Fox. Water - Supply, Demand, and the Law. Resources for the Future, Inc. Washington, 1960.

water use.

In order to project future demand for water for agricultural uses, it is necessary to study the agriculture of the area under consideration to (1) get a good picture of the agricultural industry; (2) analyze the changing trends in agriculture; (3) assist in the determination of agricultural population and employment; and (4) determine the type and volume of agricultural production and the potential for agricultural production. Before attempting to analyze the changing trends in agricultural production, and before their significance can be fully comprehended, it is important to understand the forces to which they respond. Perhaps the most important and certainly the most obvious change in the agricultural economy has been caused by the impact of technological innovations. The widespread adoption of mechanization and improved farming methods has displaced a considerable number of agricultural workers. Some of this displaced labor has been assimilated by other industries and some has become surplus to the area. Furthermore, mechanization has materially increased agricultural production, both in terms of output per man hour and in terms of total output. Even though the acreage of cropland has remained stable or, as in some areas, has declined, agricultural production efficiency has increased. This increased efficiency is largely attributable to mechanization, although increased use of commercial fertilizers, improved farming methods, soil conservation practices, and other innovations have also been contributing factors.

Mechanization, however, has not been equally rewarding in all lines of agricultural production. Increases in physical productivity of labor engaged in livestock production have not kept pace with increases in output from labor engaged in crop production even though improved breeding and the development of more efficient feeds and feeding have been widely adopted in the livestock enterprises. This is because the gains made from improved breeding and feeding have not resulted in the saving in manhours that have been realized in crop production from mechanization, even though livestock production per manhour expended has increased.

Rather than reducing manhours worked per capita, increased agricultural productivity has resulted in a reduction in the number of farms and farm population. Trends in increased productivity indicate a further reduction in farm population. There is a limit to labor displacement by mechanization, however, that many authorities believe is already near. In general it can be expected that future technical efficiency will result mainly in efficiency through increased production rather than in efficiency gained by further reduction of labor. Increased efficiencies can be expected from technical improvement and mechanization in newer methods of vertical integration in livestock production.

Analysis and understanding of the forces that condition trends in agricultural production assist in making explicit assumptions regarding future agricultural output. These assumptions may be stated as follows:

1. The downward trend in employment caused by increasing mechanization will continue, but farm population should level off and may even increase in response to increased demands for foodstuffs.
2. Improved soil conservation practices, already implemented in so many areas, will be even more widespread.

3. The trend toward diversification of crops will continue.
4. Better plant and animal breeding will help to increase farm production and income under normal conditions.
5. Higher yields per acre through use of commercial fertilizers and irrigation and higher yields per man because of mechanization are trends which will continue.

These assumptions are prerequisite to projections of farm population, farm employment, and potential of agricultural production. They do not, however, lead to a formulation of projected needs for agricultural production. Additional assumptions are necessary relative to the needs for certain types of production that help to explain trends in changes in agriculture. Based on what we know about population growth, industrial development, personal incomes, and rising standards of living, we can set forth the following postulates:

1. Considerable increase in whole milk production can be expected in response to the increase in size of nearby urban areas. Considerable increase in vegetable production can be expected also with higher personal incomes and higher living standards.
2. Continued emphasis on livestock production for meat, particularly in those areas where potential increases in capacity of the land are great, can be expected.
3. Agriculture will continue as a major support of the economy in many areas, but it is not likely to continue to account for as large a percentage of total income as it has in the past.

All of the factors considered in the agricultural economics analysis must lead primarily to two considerations: (1) The forecasting of the potential and the probable extent of agricultural production in the future; and (2) the number of people employed in agriculture. The latter is important to the consideration of municipal and industrial water supply because a segment of the population of each area will be engaged in serving agriculture. In addition, water required for agricultural uses may have tremendous impact on water supply available for other uses and on total water demand. Before it is possible to determine the impact of water requirements for agriculture on total water demand we must get some idea of the agricultural requirements for water. This will involve making projections of total farm population and numbers and kinds of livestock to determine domestic water requirements, and of the amount of water required for irrigation. Total domestic water requirements can be estimated by applying per capita use rates to population and livestock. Per capita use per person for personal and household uses can be expected to be in the neighborhood of 100 gallons per day by the year 2000. An estimate of livestock requirements can be obtained by application of the following factors: for one milk cow (for drinking and washing utensils) 35 gallons per day; for one beef cow or horse, 12 gallons per day; for one hog, 4 gallons; for one sheep, 2 gallons; and for 100 chickens, 7 gallons.[2]

Data on the amount of irrigation water needed for each acre of land are available from several sources. The best data on water requirements are those obtained from successful farmers who have reliable water supplies in the general area under study. Experiment station records on irrigation use, when adapted to actual farming practices, are also helpful in estimating farm delivery requirements. Considerable data on irrigation requirements are available from the Bureau of Reclamation, Department of Agriculture, and State agricultural colleges.[3/] The data available will lead to a determination of present total water requirements for irrigation which includes not only farm consumptive use but also farm losses and irrigation system delivery losses. What we are concerned with, however, is total irrigation requirements in the future. Here again, technology must be taken into consideration. Crop adaptation and improvement, pest control, adequate fertilization, and erosion control have removed many previous barriers to sustained high yields, particularly in the eastern United States. Engineers and other scientists are continually working on techniques of reducing irrigation system losses and farm irrigation water losses. Assumptions regarding the extent to which these irrigation losses may be reduced in the future are necessary to a projection of future irrigation requirements.

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[2] Planning an Automatic Water System. The Penn. State University, Coll. of Agr. Agr. Exp. Sta. Cir. 382, May, 1951. University Park, Penn.

IMPACTS ON QUALITY AND QUANTITY

The expanded use of pesticides may increase crop yields but the increase in yields may be at the expense of impaired quality of water for other uses. Existing evidence indicates that in areas where pesticides are used in large quantities, runoff from these areas contains enough of the undesirable soluble material that water quality is impaired. Available

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[3/] Water Facts for the Nation's Future. Langbein and Hoyt. Chap. 10 Ronald Press. New York, 1959.

evidence indicates that the natural organic and synthetic organic chemicals dissolved in the runoff from pesticide-treated areas are not removed by presently known water treatment methods. Not enough is yet known about this problem to determine whether it will have pathological effects on health. However, it is a problem with which we must be concerned when considering the development of surface supplies of water for domestic and municipal uses in those areas where large amounts of pesticides are necessary for profitable agricultural production.

After determination of the amount and distribution of precipitation in the area the effect of total water requirements for irrigation and farm domestic use on available water supply and on total water demands can be determined. This assumes of course that total water requirements and demands for other uses have already been determined. However, knowing the requirements for each use and the impact of the demands of each purpose on total available supply does not answer the question of which purposes should be served or which uses should have priority.

ECONOMICS OF ALTERNATIVE USES

It appears to me that in any water resource investigation the question of priority of use among competing alternative uses is the crucial issue. Some ordering of priority in use may be quite easy. For example, water use for human consumption undoubtedly has highest priority. Similarly, control of water to spare human lives in flood has high priority. Beyond these points, however, ordering of use is not so "clear cut", and must involve much more study. To sustain life both food and water are necessary. Abundance of both probably will not be possible in years to come. In addition to food and water, we also need those manufactured goods and those services provided by our natural resources that will enable us to maintain the standard of living to which our people have become accustomed and which have become necessary parts of our lives. This does not mean that the highest tail fins on automobiles are necessary, or the most gadgets, or two cars in every garage, or a country home in the mountains or on the water front, but rather those things that we have come to feel as necessary to civilized living. How can we best control our resources so that we will be assured of plenty of water for necessary livelihood, plenty of food, and plenty of essential manufactured goods and still have enough for such necessary things as recreation and outdoor living and enjoyment? Many solutions to this problem are possible. For example, we might: (1) Set priorities on food production and allocate the amount of resources required to meet the food goals. (2) Zone the country by regions so that each region would produce only those things to which it is particularly adapted. This would mean producing food only in those areas particularly adapted to food production of given types with the least input of natural resources. (3) Divert more of our human and financial resources to research in the field of new synthetic foods. (4) Let the pricing mechanism, and where inapplicable, legal and social means, be the guiding criterion for resource allocation. Because the latter appears to be the most practicable and the most palatable from the standpoint of a democratic way of life, I should like to pursue this possibility a little later.

If we are to attain the goal of maximization of economic welfare we must allocate water resources to alternative uses in such a manner that the goal will be realized. The objective to be attained is to help maximize economic welfare of society in total. This requires getting the proper balance between uses and weighing the gains from each use against the cost. This brings me back to the beginning of this paper - the efficient allocation of water resources between competing uses which I consider is the first major condition in meeting the goal of maximization of economic welfare.

Three steps are necessary to attain this condition of efficient allocation. First the determination of the supply of water. This includes the total quantity available to the geographic sector under consideration. It includes also the distribution of the water supply among localities and seasons of the year and its storage possibilities to alter the supply between different time periods. Second, the determination of alternative uses and the production possibilities of each use of the given water supply. The nature of these two steps is largely physical although important economic concepts are involved. Although these two steps can be accomplished expeditiously, they have little economic significance. The third step, however, is entirely economic and is the real determinant of economic use of the resource. The third step is the application of a choice criterion in determining which uses (or rather the products or services supplied by each use) are most important. These uses must also be in line with the relative wants or desires of consumers of the products or services forthcoming from the uses. In applying a choice criterion relative weights or importance are placed upon use. This generally results not in a single use but an optimum combination of uses. Ordinarily, a single use will not be extended to the point where it curtails other uses below socially desirable levels.

For a given supply of water many alternative uses exist. Let me present a simple illustration of the problem in which, for purposes of simplicity, I will assume only two competing uses. Assuming that the supply of water is known, a set of production possibilities exist for its use. The water could be used entirely for one use, say irrigation. Another alternative might be to use all of the water for another use, say to produce an industrial product. Use of all the water for a single purpose would represent an extreme. Besides these two extremes many possible combinations of uses could be made between irrigation and industrial production. Assuming that both of these uses results in products for which there is a demand, the question is: Which alternative is the optimum or socially desirable combination?

An answer to this question cannot be given until a choice criterion is applied. That is, some social ordering or some relative importance must be placed on each of the many alternatives. The selection of alternatives must beflect the changing desires of the consumers. Normally the choice criterion employed is the pricing mechanism. Consumers reflect the relative importance which they attach to each alternative use of water by the prices they are willing to pay for the products forthcoming from the alternative uses. If all water available were used by private enterprise to produce commodities and services for consumers, given a set of prices, the private firms would produce commodities and services in line with consumer preferences.

Suppose that for the given supply of water we can produce 100 units of an agricultural product valued at one dollar per unit which would result in a total value of production of $100. The same amount of water will produce 40 units of an industrial commodity valued at $2.50 per unit resulting in a total value of production of $100. If consumers are completely indifferent as to whether agricultural products or industrial products were produced with the water, all of the water could be used for either product and the economic gain would be the same - $100. However, man does not live by bread alone. The consuming society says that it wants both agricultural and industrial products. They place a value on the industrial product that is 2½ times the price of the agricultural product. This price ratio of 2½ to 1 is the choice criterion which serves to indicate the optimum use of resources. It will be to the consumers advantage to substitute water used for agricultural production by water used for industrial production as long as the substitution ratio of agricultural products to industrial products is less than the price ratio of 2½ to 1.

In our example the water supply is sufficient to produce either 100 units of agricultural product or 40 units of industrial product. If all of the water were used for either one or the other the total value produced would be $100. Society, however, wants some of both products. It is possible to produce 90 units of agricultural product and 10 units of industrial product which will have a total value of $115 with the supply of water available. In choosing this alternative, 10 units of agricultural product are being sacrificed to gain 10 units of industrial product. This is a substitution ratio of 1 to 1 which is less than the price ratio of 2½ to 1 and therefore it is to society's advantage to make the substitution. Another alternative is the production of 70 units of agricultural product and 20 units of industrial product which results in a total value of production of $120. Here we sacrifice 20 units of agricultural product to gain 10 units of industrial product. The substitution ratio is 2 to 1, which, being less than the price ratio of 2½ to 1, is advantageous. Still another alternative is the production of 40 units of agricultural product and 30 units of industrial product giving a total value of production of $115. In this case 30 units of agricultural product are sacrificed to gain 10 units of industrial product. This is a substitution ratio of 3 to 1 which is more than the price ratio of 2½ to 1 and therefore is less desirable than the production of 70 units of agricultural product and 20 units of industrial product. This situation holds generally true for water use: increased diversion of water for one purpose entails increasing sacrifices in other uses. I again emphasize, water used for one purpose should not be extended to the point where it curtails socially desirable levels of other uses. In our example, water used for agricultural production should not be extended beyond production of 70 units of product so that it will not curtail industrial production below 20 units of product. In those alternatives, such as those used in this example, where products move into the market, the rule should be: use water for the purpose which has the highest marginal value product. If each unit of water were allocated in terms of its marginal value product, a maximum addition to the social product would be guaranteed in water use. It should be emphasized that it is the marginal value productivity and not the average productivity of water that is important. Use of the marginal value productivity takes into account that (1) the physical productivity of water may decrease as more is used for a particular product and (2) the price consumers are willing to pay for the product from a particular use of water may well decline where more of the product is forthcoming. Thus, the maximum value of water used for any purpose is determined by the marginal value product forthcoming from the last unit of water used. What does this mean and how does it work? Let us assume that in an arid region where crops cannot be grown without irrigation, 5 units of water are applied to an agricultural crop. The total value product for the first unit of water used is $100; the second unit, $180; the third unit $240; the fourth unit, $280; and the fifth unit, $300. The marginal value product for each unit of water use is $100 for the first unit; $80 for the second; $60 for the third; $40 for the fourth; and $20 for the fifth. If all of the 5 units of water were used for agriculture, the total value product would be $300 and the maximum value of water per unit used would be $20 since that is the marginal value of product from the last unit of water applied. This, however, would not be the most efficient use of the five units of water. A total value product of more than $300 could be obtained if the water were not all used for agriculture. Suppose that when used for the manufacturing of an industrial product the 5 units of water produce a total value of $55 for the first unit of water used; $100 for the second; $135 for the third; $160 for the fourth; and $175 for the fifth. Marginal value products are $55, $45, $35, $25, and

$15. Since the marginal value products of the first and second units of water used for the industrial product $55 and $45, are higher than the marginal value products of the agricultural commodity forthcoming from the fourth and fifth units of water used, $40 and $20, respectively, it will pay to use only three units of water for agriculture and two units for production of the industrial commodity. Allocated in this way the total value product from both uses is $340 as compared to $300 when all the water is used by agriculture.

Hence, a general principle has been indicated for attainment of the first major condition - the efficient allocation between competing uses. The pricing mechanism can be used as the choice criterion reflecting consumer desires to water uses. However, for many uses of water, the pricing mechanism cannot be used as a choice indicator. For example, there is little opportunity to divert water from irrigation or power production to recreation purposes. In some instances, such as in the case of municipal water supply, prices paid for water are administratively determined and are not necessarily the prices people would be willing to pay for water produced by private competitive firms supplying water for municipal needs.

Although the pricing mechanism is an insufficient basis for final control of water use and allocation, the principle of the choice criterion should not be discarded. If the most efficient use or control of water is to be attained, the pricing mechanism as a choice criterion must be retained. Where the pricing mechanism is insufficient for measuring and reflecting the relative values of water in its different uses, other means of measurement must be found. Some means of measuring the relative values or weights for water uses where the pricing mechanism does not apply must be found so that relative values can be compared to the production possibilities of water and a choice of uses made in line with these two phenomena. In many cases of water resource development, optimum choices of use will need to be effected with some combination of price and legal mechanisms.[4]

CONCLUSIONS

In this paper I have attempted to show how we might arrive at the total water demand for agriculture. Water requirements for agriculture, being of a physical nature, are not difficult to determine. After the requirements have been determined it is not a difficult task to determine the relative effects of water demand for agricultural uses on total water demand in a quantitative sense. This determination, however, is not the real problem. The real problem of effects of water requirements for agriculture on total demand for water is economic in character and is not so easily determined.

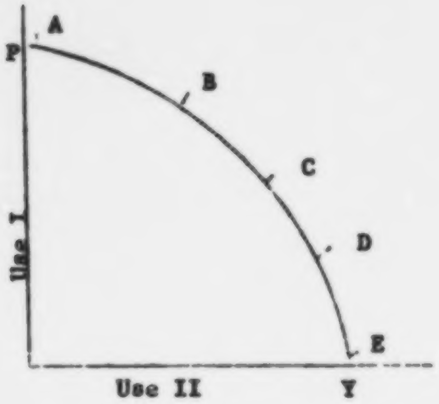
The real problem facing the American people today in water resource use and development is: How should our scarce water resources be used to the greatest benefit to society? I have tried to point out some of the considerations that are involved in seeking an answer to this question. As I have indicated, insufficient knowledge is as yet available and considerable work will be required before a satisfactory solution can be attained.

4/ For a more detailed technical discussion see Heady and Timmons, Economic Framework for Water Resources. Iowa's Water Resources. Iowa State College Press, Ames.

W. G. Eichberger
United States Public Health
Service, Region IV

TECHNICAL APPENDIX

A conceptual or schematic illustration of the problem concerned and its solution (i.e., the major condition of allocative efficiency) can be used to point up the requirements in attaining the most efficient uses of water. For the given supply of water, there exists alternative uses such as are illustrated in the following diagram.



Assuming that we know the supply of the water resource, a set of production possibilities exist for its use. (Here we assume only two competing uses). The production possibility curve is labeled PY in the diagram. It shows all the possible combinations of the two uses which can be attained from the given stock or supply of water. The water might be used entirely for Use I. This extreme allocation of the given water supply to Use I would be represented by point A. Another alternative allocation would be point E; use of the entire water supply for Use II. But besides these two extreme allocations of water, we could select many possible combinations of uses. For example, we could produce much of Use I and little of Use II, as at point B; much of Use II and little of Use I, as at point D; half of Use I and half of Use II, as at C; or any of the other possible combinations along the production possibility curve PY. The optimum combination depends upon price ratios and substitution ratios. Profit is at a maximum if the substitution ratio between uses (or products forthcoming from uses) is equal to the price ratio. This principle can be illustrated with the following tabular example.

Selecting Alternative Use for Water

Production of I	Production of II	Substitution ratio: amount of I sacrificed to gain 1 unit of II	Profit or value of product with prices of $1 per unit of I; $2.50 for II
100	0		$100
		1	
90	10		115
		2	
70	20		120
		3	
40	30		115
		4	
0	40		100

Profits can be increased by extending Use II at the expense of Use I as long as the substitution ratio of Use II for Use I is less than the price ratio, $\frac{(\text{price of Use II})}{(\text{price of Use I })}$. Since the substitution ratio between the first two uses is only one, and is less than the price ratio of 2.5, the second combination is preferable to the first. The third combination (70 of I and 20 of II) also is preferable to the second since the substitution ratio of 2 in going between the second and third combinations, is still less than the price ratio of 2.5 However, the fourth combination is not preferable to the third since the relative amount of I sacrificed to gain one more unit of II is more than proportional to the greater weight placed on II by consumers.

If consumer preferences change so that Use II has 3.5 times as much value to them as Use I, the optimum combination then becomes 40 of I and 30 of II (i.e., with prices of $3.50 for II and $1 for I). Or, if preferences change to include a price of $1.20 for I and $0.60 for II (a price ratio of 0.5) the optimum combination is 100 of I and none of II, since the substitution ratio (in going from the first to second combination) is greater than the price ratio of 0.5, the relative importance placed on the product of Use II as compared to Use I.

The foregoing presentation is in the manner of a simple arithmetical example of optimum allocation of water uses. A more accurate analysis of the procedure involved can be shown by a series of production possibility curves and relevant community indifference curves.

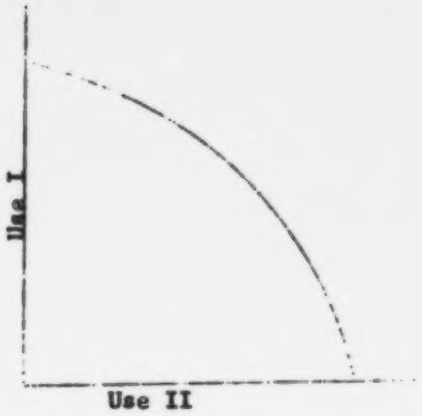


Figure 1. Production possibility for water uses.

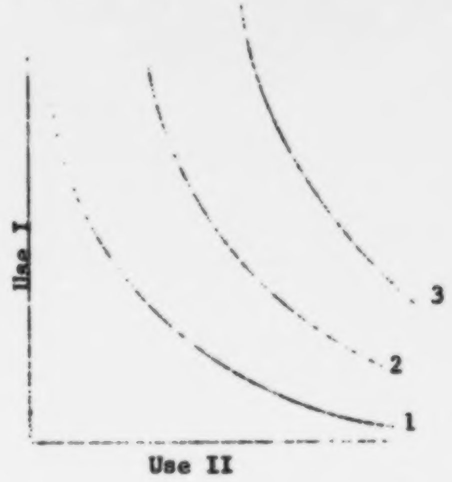


Figure 2. Indifference curves for relevant community.

Figure 1 includes production possibilities of the nature presented previously. Figure 2 includes a system of indifference curves for the relevant society or community. Each one of the system of indifference curves shows the combinations of products from Uses I and II which gives consumers the same level of satisfaction. The goal of consumers, of course, is to select a combination of products or uses which allows the highest level of satisfaction. Hence, in Figure 3, we superimpose the indifference system of Figure 2 over the production possibility curve of Figure 1.

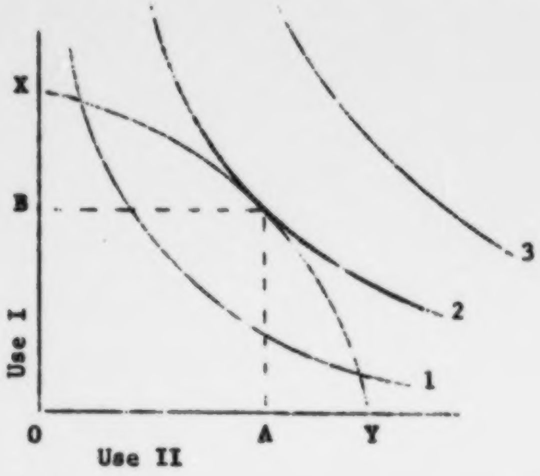
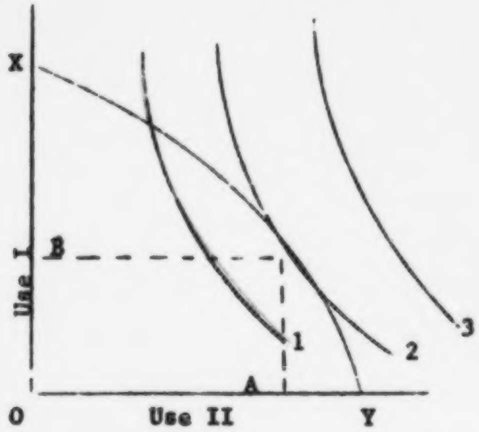


Figure 3. Combinations of production possibilities and indifference curves.

We then find the highest indifference curve (i.e., the highest level of satisfaction) which can be attained with the given resource supply. Indifference curve 2 is such a curve; this level of satisfaction can "just be attained" with the water available. While curve 3 allows a higher level of satisfaction, it cannot be attained with the given possibility curve. Curve 2 represents the optimum combination of Uses I and II by its point of tangency with the production possibility curve. At the point of tangency, the amount of

Use I which must be sacrificed to gain an additional unit of Use II is just equal to the value which the consuming society attaches to Use II as compared to Use I. It is this ratio of preference or value for consumers of the products which is reflected back to the users of resources. Hence, the optimum combination of uses is not all of I or all of II, but a combination including OB of Use I and OA of Use II. If consumers changed their preferences for the two products in the direction of Use II, the entire family of indifference curves would take on a greater slope as shown in Figure 4, since the slope of the indifference curves expresses the relative preferences of consumers.



Hence the point of tangency would come closer to the aliscissa; relatively more of Use II and relatively less of Use I would be necessary to allow maximum consumer satisfaction or economic welfare assuming an equitable distribution of the product.

NOTES

Demand for irrig water is seasonal. 1 or 2 crop growing periods
10 acre ft for each acre. in west use 4 acre ft.
1/2 - 1 1/4 acre ft in more humid areas ✓
(1000 gals of irrigation water produces 5¢ worth of agr product)

Fleas
Can't hear
if you cut off
all 6 legs

ESTIMATING FUTURE WATER DEMAND

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INTRODUCTION

This paper will present some of the problems typically encountered in making estimates of the water requirements which may be expected to accompany the projected populations and economic activities, previously discussed by Mr. Torget. The paper is intended to serve as a basis for discussion leading to conclusions. It is pointless to deny that I already have certain personal convictions on the subject---as the reader will no doubt detect.

GENERAL OUTLOOK

We believe that the planning of water resource utilization can and should be approached with optimism. A noted spokesman has been widely quoted as saying, in speeches made throughout the state of Texas this past year: "Within the next 50 years, the number one problem in Texas may well become, where to get a good drink of water." Not to disparage the speaker, whose purpose to get the attention of a well-fed luncheon audience was admirably served by this catch phrase, it must be pointed out that drinking water is a negligible part of total water demands. To be sure, a prudent man would not sit down in the middle of a desert, waiting either to have water brought to him or die of thirst. But then, he never could do that in the past.

There is, happily, a growing awareness that water is a commodity like any other, and can become responsive to the same economic laws that govern other goods and services. This viewpoint was ably presented by Mr. Hines, in his paper, "Role of Price in Water Resource Allocation." 1/

This paper is written in the environment of Region VII and some of its statements may not apply to other parts of the country. With that qualification, it can be said that there is ample reason to expect that water can be made available in quantities sufficient to meet any reasonable projection of demand, at prices within economic range. This is said in full knowledge of, and in spite of, the voices of those whom John Vandertulip 2/ has called "Criers of Doom".

THE COMPONENTS OF WATER USE

Water serves many purposes, and this discussion is confined to the projection of municipal-and-industrial water requirements. The hyphens are there to emphasize that we seek a single final answer, whose total value will include all of the water uses which the words municipal and industrial, together or separately, connote.

1/ Hines, Lawrence G., "Role of Price in Water Resource Allocation", Journal of the Sanitary Engineering Division, ASCE, January, 1960.

2/ Chief Engineer, Texas Board of Water Engineers

The first sentence of the report to the Select Committee, Print #7, [1] reads in part: "Presented....are data on the quantities....of water presently supplied through municipal systems....(and) estimates of the quantities..... required for municipal purposes in....the year 2000....". (Underlining supplied.) I suggest that the author changed horses in midstream of that sentence. Two examples will illustrate the distinction. At Tulsa, Oklahoma, 38 per cent of the present output of the municipal water department is sold to two oil refineries. At San Antonio, Texas, the largest department store has its own well, as do many other commercial establishments and some residences. The first example illustrates municipally-supplied industrial water, and the second, "self-supplied" municipal water.

It is admitted that defining municipal water as water supplied through "organized community water facilities" [2] has advantages. It facilitates processing of reported data by machine methods, and it subdues the element of judgment in statistical analyses. Nevertheless, it is believed that a preferable basis for future projections is to subdivide water use according to purpose, and not according to the *modus operandi* by which the water is delivered to users.

1/ *Future Water Requirements for Municipal Use*. Report by the Department of Health, Education, and Welfare, to the Select Committee on National Water Resources, United States Senate, published as Committee Print No. 7, 1960.

2/ *Municipal Water Facilities, Communities of 25,000 Population and Over*..., U. S. Public Health Service, January, 1958.

Fortunately, it happens that in many cases, and perhaps in a majority of cases, those industries whose water demands are significantly large, have their own facilities. The remaining industries are either so small, or so much a part of any typical community, that their water use can, without serious error, be included with other usage in a single municipal figure. But the investigator should be on the lookout for exceptions to this generalization, and make appropriate adjustments.

For the type of water resource planning with which we are concerned, there will be no "self-supplied" users. The goal of resource planning is to present an over-all appraisal of supply and demand for a study area. Supply can come only from one or both of two sources--surface and ground waters. Both sources are supplied by nature, and man can only effect some modification in the areal and temporal distribution. Of course, some large streams may require little or no artificial regulation, but this in no way alters the basic truth. Water may be self-pumped or self-piped---but it will not be self-supplied.

For projection purposes, the separation of water demand into a multiplicity of component parts is of questionable merit. The historical records of municipal water use are of dubious accuracy even for the total quantity used. Few operating water companies can do more than guess at how their total output is divided among different purposes. Evidence for that statement is to be found in examination of the 1957 Inventory of Municipal Water Facilities. [1]

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[1] Ibid.

Columns 15 and 16 of the Inventory report the answers to the question of how total output is divided into four parts: Domestic (Residential), Commercial, Industrial, and Public-and-other. Approximately 62 per cent, of 580 reporting communities, either did not answer the question or gave incomplete answers. Another 13 per cent gave answers whose sum does not equal the reported total output. Three examples will be cited to support questioning of the validity of answers for the remaining 25 per cent.

The City Water Board of San Antonio, Texas, was among the 25 per cent reporting consistent answers. I was employed there at the time of the inventory. We were justifiably proud of the records kept by the Water Board. But those records were not kept in such manner as to yield an answer to the question of four-part breakdown---somebody guessed at it.

Another city reported total output of 10 mgd, divided 3-3-3-1; a breakdown of beautiful symmetry but doubtful validity.

In sharp contrast to the reports from other states, in Wisconsin every city but one gives a consistent breakdown. This means either that Wisconsin operators are far ahead of their neighbors in detailed accounting for water, or else the state data were arbitrarily adjusted for consistency in a central office.

Nothwithstanding what has been said, further study of the breakdown and pattern of water use is worthwhile. I believe it will be profitable to pursue local studies of an intensive nature, as a complement to the extensive coverage of nationwide inventories.

FACTORS AFFECTING WATER DEMAND

In the language of the mathematician, water demand will be treated as the dependent variable. Independent variables or parameters, upon which it depends, may be listed as follows:

1. Population.
2. Time (trend).
3. General state of the economy.
4. Living standards of families.
5. Climate.
6. Size of city.
7. Price of water.
8. Type and size of industry.
9. Accuracy of measurement.

Ideally, the scientific approach to investigation would be to allow each parameter to vary in turn, while holding all others fixed, and to measure the observed effect. Unfortunately, it is not possible to isolate any single variable completely from the others---nor is it possible to use another technique common in model studies and group them into dimensionless combinations, thereby reducing the number of independent variables.

An effort has been made to find examples for which one parameter was of predominant influence--either because the others did not vary or because the observed effect occurred in spite of counter-influence of other parameters. As each parameter is discussed, the examples will be presented.

1. Population

Because population is the most important single factor affecting municipal use, it is customary to express the ratio in gallons per capita day (gpcd). Except as qualified, other variables will be examined as to their influence on per capita use.

2. Time

Figure 1 shows the trend of municipal water use at Austin, San Antonio, and Oklahoma City. Gallons per day per service connection, rather than per capita, were plotted because records are available directly in that form for two of the cities. For Oklahoma City, pumpage data, but not the number of service connections, are available for each year. Because of necessary adjustment to permit plotting on a comparable basis, the Oklahoma City curve should not be considered definitive except as an indication of general trend. Our primary concern here is the general shape of the trend curves. The U-shape which is characteristic of all three records leaves wide latitude for opinion as to what the future trend will be. For extrapolation 50 years into the future, it is desirable, on one hand, to consider the longest available period of past record. Examination will show that a line drawn approximately through the earliest and most recent points would incline downward into the future.

On the other hand, a sharp upward trend is evidenced in the last 25 years. The slope of this 25-year trend translates into an average increase in per capita demand of one to one-and-a-half gallons per day per year. Apparently, this is the evidence upon which many forecasters have predicted future acceleration rates of such magnitude.

A third possibility exists, which is not shown on Figure 1. Records of the last four or five years exhibit a level trend.

Somewhere among the possible extremes lies the most probable answer. In my own opinion, it is unreasonable to expect the acceleration rate of the past 25 years to continue unabated for fifty more years. But I must disagree with those who would ignore it entirely.

In reaching a decision, it would be most helpful to know the causes of the shape of the trend curves. Here the impossibility of isolating the variables becomes apparent.

Conjecturally, the downward trend of the early years reflects increase in metering. Unquestionably, metering has a significant effect on water usage. When it is not metered there is little incentive to call a plumber to repair leaks--and a leak can easily waste far more water than is beneficially used.

Possibly the low point in the mid-thirties and high point of the mid-fifties reflect the influence of our third variable, the general level of economic activity. In pursuit of this idea, the graph of gross national product was also plotted on Figure 1. The low point of the curve corresponds to the middle of the Great Depression, and time may show the high point to coincide with the peak of a boom period. However, the hypothesis doesn't stand up too well under closer examination, especially in the period from 1920 to 1935.

4. Living Standards of Families

Table 1 and Figure 2 show the result of a part of an intensive study of water use patterns in San Antonio, Texas. An unusual opportunity to isolate one variable from the others is made possible by the fact that, since 1957, the San Antonio Water Board has kept separate records of consumption in each Census Tract. The city was divided at the time of the 1950 census into approximately 100 of these tracts.

Ten Census Tracts were selected for investigation. These tracts were chosen because: (1) each tract is predominantly single-family residential, with a minimum of commerce and no industry; (2) the ten tracts cover the range from luxury to sub-standard class of neighborhood; and (3) each is homogeneous with respect to its economic class.

1960 populations given in Table 1 are the preliminary United States census values, obtained through the courtesy of the San Antonio Chamber of Commerce. Populations for other years were obtained by interpolation, using number of service connections as a guide. Water consumption data are from the records of the City Water Board. Property values were obtained from records of the Bexar County Tax Assessor-Collector. Assessed valuation was first determined by averaging approximately fifty random samples for each tract. The average assessed value was then divided by 28 per cent, on the advice of tax office personnel, to convert to actual market value.

Table 1
Residential Per Capita Water Consumption
San Antonio, Texas

Census Tract	Average Property Value	Population				Average Water Consumption, gpcd			
		1957	1958	1959	1960	1957	1958	1959	1960
A-1	$ 3,000	14,000	14,000	14,000	14,000	60	59	70	60
A-2	4,400	6,400	6,500	6,600	6,700	83	78	84	84
B-1	5,900	4,400	4,420	4,350	4,300	106	98	101	96
B-2	6,400	4,440	4,450	4,420	4,440	114	107	110	109
C-1	8,600	5,040	5,040	5,040	5,040	127	111	113	111
C-2	9,700	10,320	12,180	13,900	15,200	143	94	98	97
D-1	19,700	5,230	5,970	6,950	7,760	195	190	208	208
D-2	16,600	4,900	5,760	6,760	7,150	186	157	202	183
E-1	20,800	5,040	5,130	5,220	5,600	252	212	224	256
E-2	21,400	2,590	2,530	2,480	2,440	262	225	260	280

I would have preferred using per capita income instead of property value as a measure of the standard of living in each Census Tract---but the figures are not yet obtainable from the Census Bureau. Nevertheless, the high degree of correlation between standard of living and per capita water use, and the tremendous influence of standard of living, are clearly apparent in Figure 2.

Annual rainfall was above normal in all four of the years of record.

The price of water was about 30 per cent higher in the two tracts, E-1 and E-2*, than in the others. This is because they are separately incorporated satellite cities and are charged the outside-city-limits rate of the San Antonio waterworks. It appears that, for this luxury class, the premium price of water didn't noticeably affect its use.

5. Climate

Several investigations of the relationship of per capita use to rainfall have been made in the Region VII office. The results can be summarized by saying that, when annual rainfall is more than about 45 inches, no discernible effect is caused by further increase in amount. Below 45 inches per year, there is a noticeable effect, per capita demand at 15 inches of rain averaging about [illegible] 20-30 gpcd more than ~~times~~ the demand at 45 inches.

One illustration of observed effect of rainfall will be presented in the discussion of the next parameter, size of city.

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* Census Tract designations used herein are not the actual tract numbers.

Before leaving the subject of climate, it is appropriate to suggest that more consideration should be given to drouth frequency analysis in the study of both supply and demand. Since the purpose of storage impoundment is to assure the supply of water during drouth periods, it is logical to estimate what the demand will be under the design drouth condition that is used in reservoir yield studies.

The governor of Texas said recently that the drouth of the middle fifties was the worst in 600 years. Without questioning the accuracy of estimate of that recurrence interval, it can be questioned whether our "prudent user" would be willing to pay the cost of avoiding some curtailment in water usage once every 600 years. Statements of dependable yield from a reservoir should be accompanied by a statement of the drouth frequency, or recurrence interval, used in the analysis.*

6. Size of City

Figure 3 was plotted from data collected for a 46-county regional study being made for the Trinity River Watershed and adjoining areas. Each point represents the average per capita use of all community water systems (for which records are available) in a county. Included in the group are Harris County (Houston), Dallas County, and Tarrant County (Fort Worth).

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* Although low-flow augmentation is outside the scope of this paper, the same viewpoint applies.

The fortuitous occurrence of an abnormally wet year immediately following a record drouth year (1956) offers a good opportunity to see the effect of rainfall extremes. It will be seen that per capita demand in 1956 averaged about 20 per cent higher than in 1957.

The astonishing thing about the data plotted on Figure 3 is the indication of limited effect of size on per capita demand, even though sizes range from a thousand to a million people. Statistical regression lines for each year, and their equations, calculated by least squares, are shown on the graph. They were calculated because we didn't believe our eyes, and they are not recommended for general use. I am not ready to say that this evidence shows that per capita use does not increase with size of city---but I am no longer willing to accept such an assumption without doubts. Perhaps the country town is disappearing, along with the country girl.

7. Price of Water

In considering the effect of price on water demand, three basic facts should be kept in mind. These are: (1) it is delivered price, not cost of source development, that is significant; (2) for legal, political, and social reasons, the role of price has been greatly restrained; and (3) it is incorrect to generalize that the unit price of water will go up everywhere.

The cost of source development is usually a small part of delivered price of water. In an increasing number of cities the water bill includes a sewer service charge, which may or may not be separately itemized. (In Dallas it is not.) Some cities subsidize the cost of water service from general tax funds; others use water sales as a source of municipal revenue for other purposes.

Legal aspects can be illustrated by the following example. One might ask why the holder of a water right on the Texas coast persists in using the water to grow rice when the dollar return would be much higher if it were used in industrial production. The answer is that he possesses only the right to use the water for a specified purpose, irrigation, and not the authority to sell it. Society as a whole might gain from reallocation of scarce water to higher-yield usage---but the incumbent water-right holder stands to lose what he has and gain nothing. The pressing question is, "Whose water is it?". Waiver of claim by the federal government still leaves the gamut of claimants, from private citizen, to city, to county, to water district or river authority, to state.

The costs of impoundment, treatment, and transmission of water respond dramatically to the effect of mass production. Many a small town is experiencing critical problems of high-cost water precisely because the demand is small.

I shall resist the temptation to elaborate further on a pet subject, and simply say that price is expected to play a role of increasing importance in the future.

It is difficult to find evidence of significant effect of price on water usage in Region VII. Apparently this is because the cost of water is a small part of either the cost of living to families or the cost of production in industries. Only one example has been found for which a comparison can be made---the cities of Abilene and Brownwood, Texas. Investigation of the records disclosed the following facts:

1. The cities are located about 80 miles apart.
2. Abilene is three times as big as Brownwood.
3. Abilene is growing rapidly, while Brownwood lost population in the last 10 years.
4. Rainfall at Abilene averages slightly less than at Brownwood.
5. Per capita income is higher at Abilene.
6. Neither city is highly industrialized.
7. Contrary to expectations, per capita water use for several years past has been consistently higher at Brownwood than at Abilene--about one-and-a-half times as much.
8. The water bill for a typical family, using ten to fifteen thousand gallons a month, would be almost twice as high in Abilene. It appears, therefore, that price is exerting an influence here which counteracts all other factors.

8. Type and Size of Industry

Except for possibly half a dozen industrial categories in which large quantities of water are used, I believe that industrial water can be included with all other uses in a single per capita figure---at least for large metropolitan centers. Care should be exercised in the investigation, preparatory to making a projection, to insure that the water usage from all sources is included in the total present use. The total may then be separated, or not, as judgment dictates, into municipal and industrial parts. The decision--for reasons previously stated---should not be based solely on whether particular water users are currently buying water from the municipal system.

Where the special large-water-using industries exist, their water demands are apt to be quite large, sometimes far overshadowing the municipal use.

9. Accuracy of Measurement

This is not, of course, a proper variable upon which it could be said that water use depends. It is included here because of personal conviction that inaccuracies in measuring, compiling, and publishing data constitute a major reason for difference in the reported use of water.

It is by no means obvious, to the management in many operating water companies, that it is necessary to account precisely for the total quantity of product delivered. A large part of the cost of rendering water service is made up of fixed capital and operating expenses, not directly related to the amount of water delivered. The front office is primarily interested in revenue, and many of our largest water utilities rely, like the telephone company, on a system of flat-rate monthly charges as the major source of this revenue.

The design engineer is concerned with ability of the system to meet peak rate demands. The pump station operator governs his plant output by the pulse of the distribution system as evidenced by strategic pressures or the height of water in elevated tanks.

It is apparent, then, that none of these people are vitally interested in the annual output of water. Only for long-range planning of source developments is this information indispensable.

The second major reason for inaccuracy is the difficulty of measuring the quantity of water dispatched from a pumping station. Since it flows continuously but unsteadily, it cannot be counted by discrete units, as can sacks of potatoes or carloads of coal.

Typical meters measure rate of flow indirectly by its relationship to some measurable pressure difference; the instantaneous rate is translated and integrated mechanically into total quantity. To be sure, these meters can be and are built to a high degree of precision--but maintenance by highly trained specialists is required for continued accuracy. Furthermore, they are expensive, and many small water systems do no have them.

Improvement in the completeness and accuracy of data may be expected to result from education in the importance of water accounting. The operator needs the motivation of knowing why he is doing the job, and training to teach him how to do it.

The growing use of the techniques of mathematical statistics, facilitated by electronic computers, can greatly improve our understanding of the significance of masses of data. It is well to bear in mind, however, that no amount of statistical manipulation can compensate for gross inaccuracies in raw data--and that the electronic computing machine reproduces flawlessly any mistakes fed into it.

PROJECTION METHODS

Future water demand may be obtained by: (1) direct projection of annual quantity of water, from the amount used in a base year; (2) projection of population and an all-inclusive per capita use factor which, multiplied by this population, gives total water demand; or (3) projection of population as before and selection of appropriate multipliers to give separate components of water use. Each method has advantages, and each has been used, at one time or another, in the reports prepared by the Region VII staff.

The first method is the simplest, the most direct---and probably the most vulnerable to criticism. Implicit in its use is the assumption that population and water-using activity will grow apace with the projected water demand. There should be, but isn't always, the additional implied assumption of the presence of the other factors which, in turn, cause population to grow. The water department of one of our major cities has the catchy slogan: "Podunk grows where water goes". Critics like myself would quibble that the slogan is worded backward; they mean: "Water goes where Podunk grows".

In my opinion, the second method is the preferred one of the group unless there is good reason to depart from it. The investigator would examine all of the evidence, weigh the evidence with regard to the parameters discussed in the preceding section, and render an opinion. That is, he would select for the target projection year a single per-capita number embodying municipal-and-industrial water, and multiply by the projected population. I would say that this method can be applied to large metropolitan centers in which there is not disproportionate activity of one of the special, large-water-using industries.

The third method is, or should be, a modification of the second. I would split off, for separate projection, whatever is special, unusual, or atypical at the particular place. All the rest of the water demands could still be incorporated into a per capita figure and called municipal. The projection technique for the special component would depend on its nature. For some industrial categories, the preferred approach might be to project total production and multiply by water use per unit of product. For others, the multiplier might be water use per employee. A third possibility is to make a direct assumption of percentage increase in quantity of water from analysis of the potential for growth in that industry as determined by the resources available to support it.

In selecting factors for projecting industrial use, every effort should be made to obtain local data. Unit water use within many industrial categories is so highly variable as to render virtually useless the national or regional average figures. The chemical industries present an especially knotty problem. We can do little more than guess at what the products of chemistry will be fifty years hence. (Incidentally, this writer deplores the inordinate fear of using that word, "guess"; the substitution of euphemisms seldom fools anyone.)

In contrast to industrial demand, it is confidently expected that municipal (population-oriented) water requirements will vary within rather narrow limits. I believe the time is approaching when we will be able to draw iso-per-capita lines on a map of Region VII and to use them for estimating municipal demand. This will require, first, rejection of incorrect data in the past record, and then adjustment for the influence of rainfall and standard of living.

We do not yet have firmly adopted numbers for placing on such a map. I am convinced that they will be substantially higher than those given by the Public Health Service to the Senate Select Committee---particularly the figures of 114 and 106 gpcd for the Western Gulf (year 2000) published in Table 5 of Committee Print No. 7. I suggest, for the year 2010, a range from about 140 gpcd in the humid, to about 230 gpcd in the semi-arid, parts of Region VII. (We have not made detailed studies in the arid part, New Mexico and extreme West Texas.)

Finally, if it is concluded that the best we can do is define a range of values within which the answer lies, then the numbers should truly reflect a range. To speak of a "medium" value of 114 gpcd and a "high" of 106, is both contradictory in terminology and ridiculously narrow in latitude. If "that's the way the ball bounces" as the result of a whole series of judgment decisions made in arriving at answers, then the ball should be bounced again.

SUMMARY

Despite perplexing questions as to whose water it is, water is a natural resource which can be considered to respond to the same economic laws that govern other commodities.

Objective water resource planning can be substantially bereft of funereal aspects, and approached with confidence and optimism. We are not about to run out of drinking water in Region VII.

For the purpose of estimating future demands, water use should be subdivided into as many components as will improve the accuracy of the sum of its parts -- and no more.

Certain methods of subdivision have been suggested, along with suggested methods of approach to the problem in different circumstances.

Examples have been cited to illustrate the influence, or the absence of influence, of parameters commonly considered to have significant effect on water demands.

Estimates of future water requirements should take into account both general trend and cyclical variation. A drouth frequency should be adopted as one of the basic premises of planning studies, and both supply and demand should be estimated for the climatic conditions of the design drouth.

Average per capita use of water will continue to rise as an increasing percentage of the population moves up to higher standards of living.

Suggested values for Region VII are 140 to 230 gpcd in the year 2010 - the range reflecting primarily the influence of rainfall under design drouth conditions. Adjustments should be made, as local investigation indicates, for the effects of such parameters as: availability and price of water; types of industry; and, perhaps, size of city.

The Public Health Service should review its position as established by the report to the Senate Select Committee, and make some upward revisions---particularly of the figures in Tables 5 and 7 (Committee Print No. 7) for the Western Gulf and Ark-White-Red water resource regions. Our position is weakened when we cannot cite our own publications in support of conclusions.

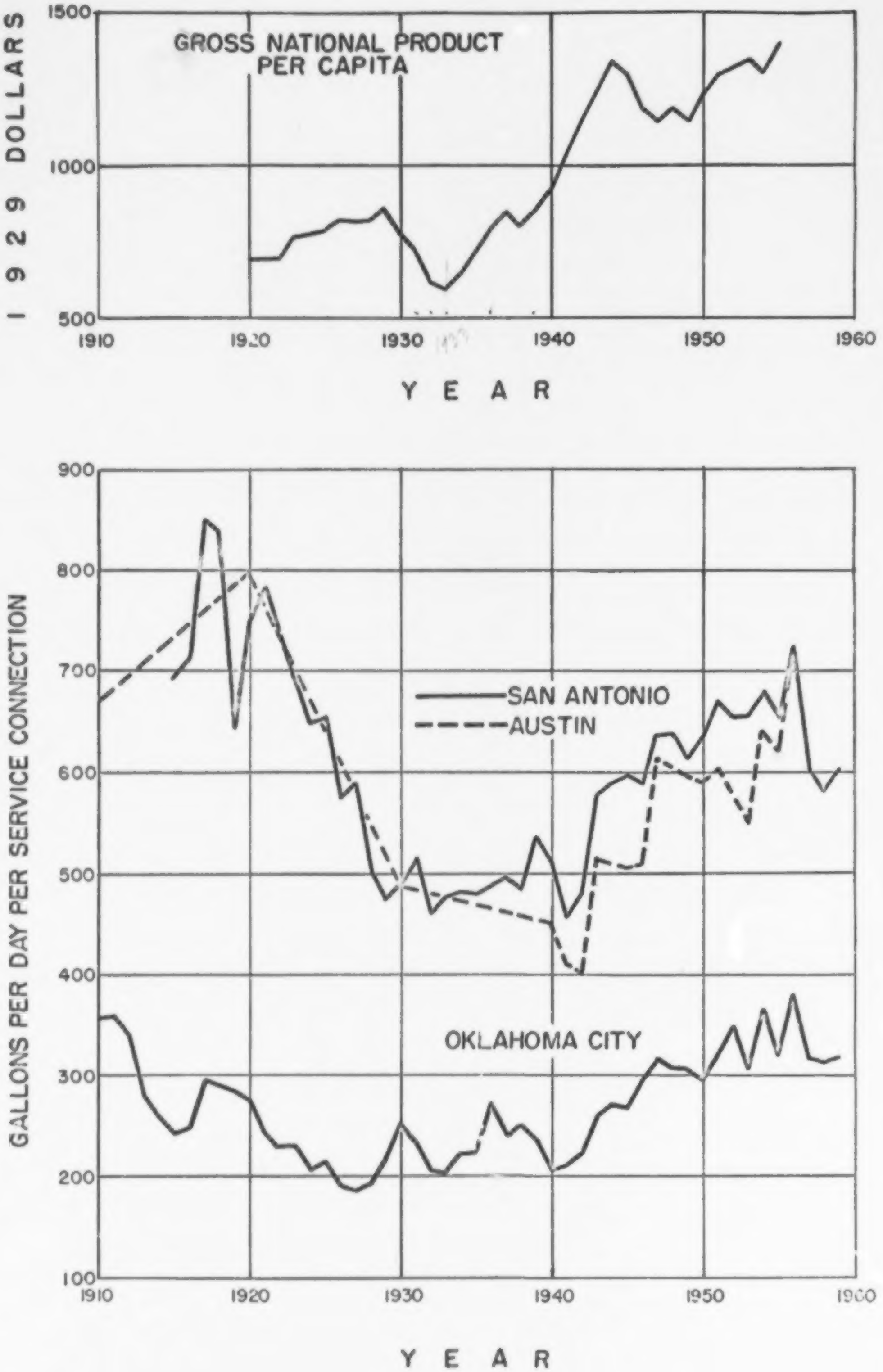
GROSS NATIONAL PRODUCT PER CAPITA
1929 DOLLARS
1500
1000
500
1910
1920
1930
1940
1950
1960
YEAR
GALLONS PER DAY PER SERVICE CONNECTION
900
800
700
600
500
400
300
200
100
SAN ANTONIO
AUSTIN
OKLAHOMA CITY
1910
1920
1930
1940
1950
1960
YEAR

FIGURE 1

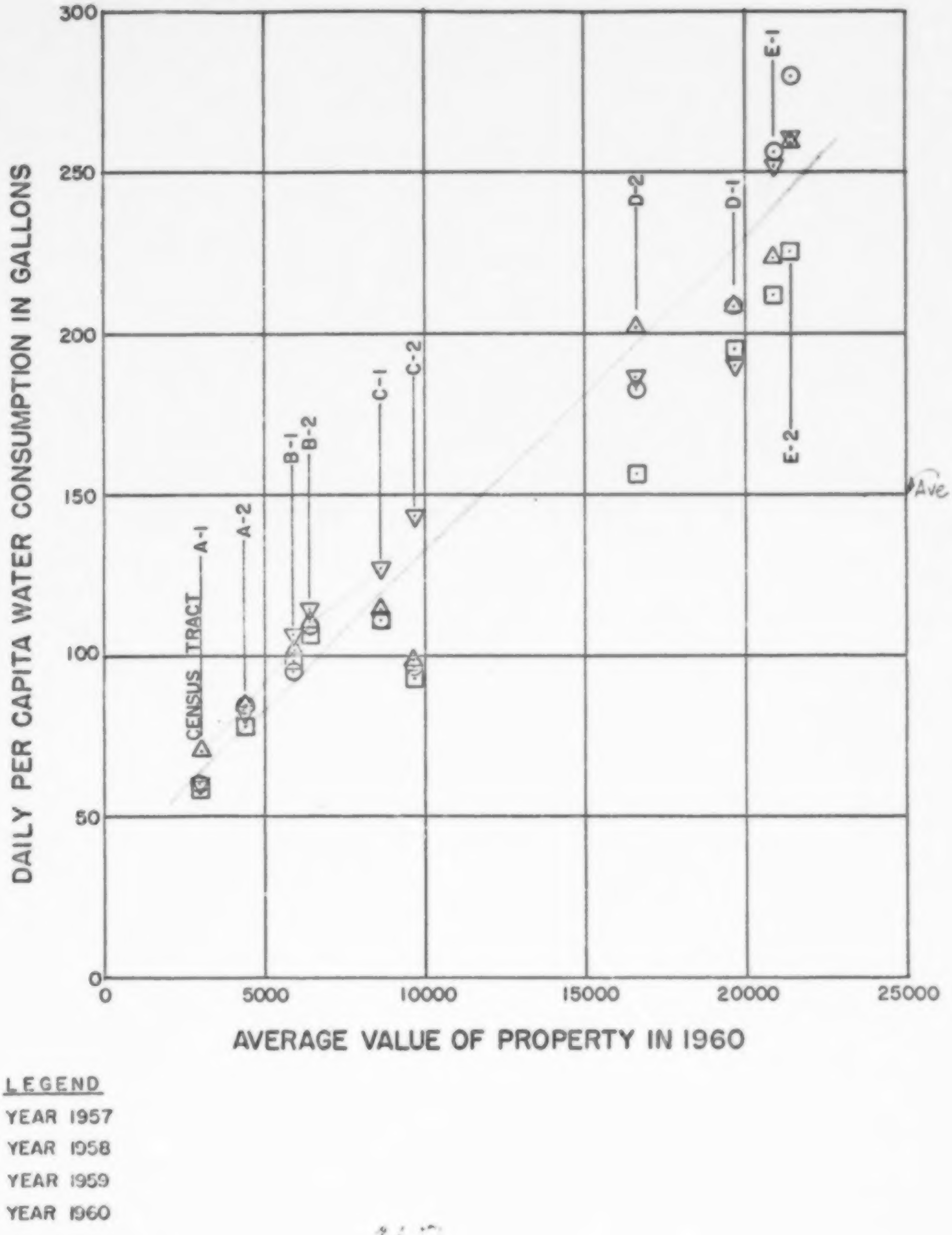
DAILY PER CAPITA WATER CONSUMPTION IN GALLONS
300
250
200
150
100
50
0
0
5000
10000
15000
20000
25000
AVERAGE VALUE OF PROPERTY IN 1960
CENSUS TRACT
A-1
A-2
B-1
B-2
C-1
C-2
D-2
D-1
E-1
E-2
Ave
LEGEND
▽ YEAR 1957
⊡ YEAR 1958
△ YEAR 1959
⊙ YEAR 1960

FIGURE 2

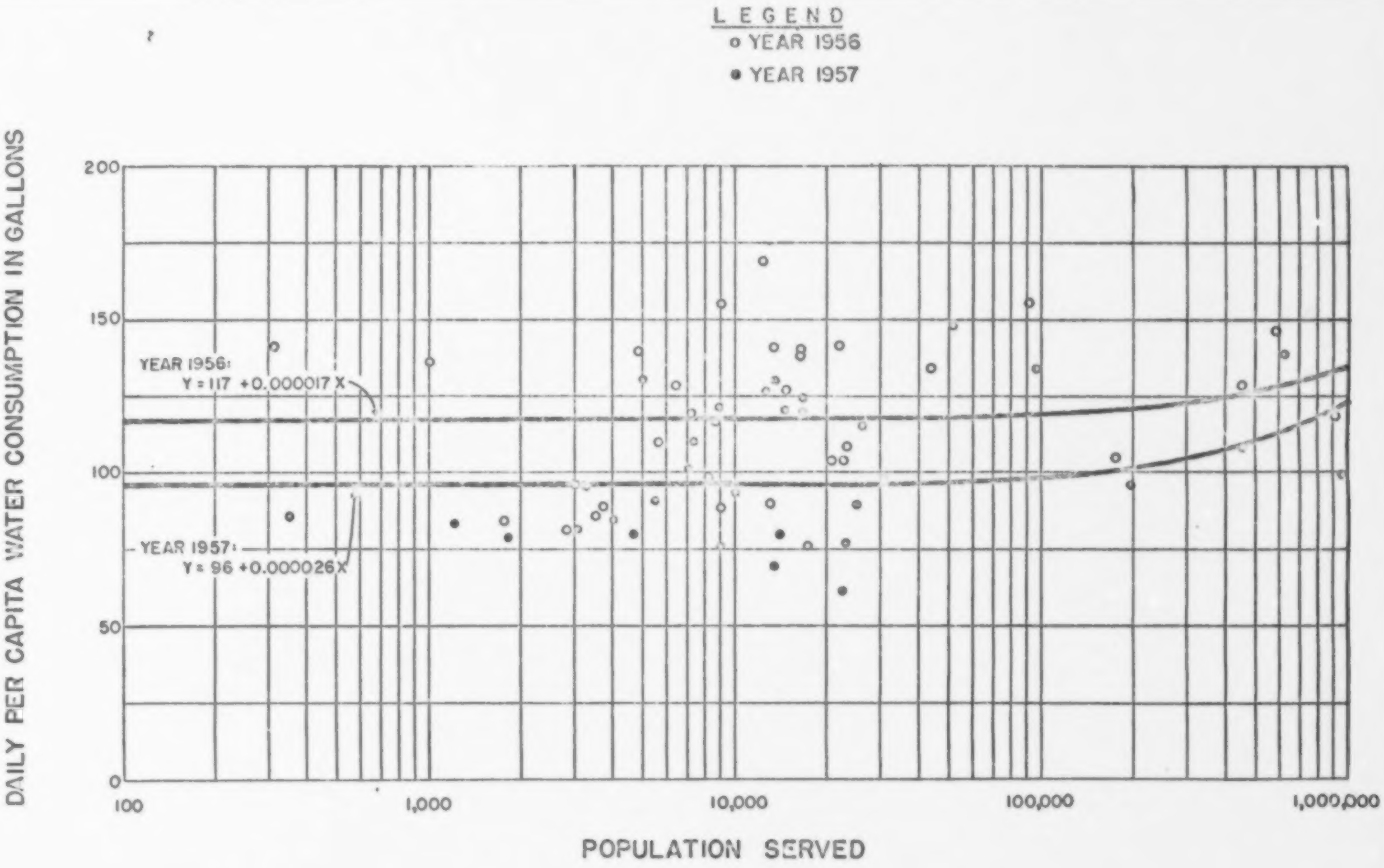
LEGEND
o YEAR 1956
● YEAR 1957
DAILY PER CAPITA WATER CONSUMPTION IN GALLONS
200
150
100
50
0
YEAR 1956:
Y = 117 +0.000017 X
YEAR 1957:
Y = 96 +0.000026X
100
1,000
10,000
100,000
1,000,000
POPULATION SERVED

FIGURE 5

NOTES

DALLAS YEAR 2000

	POPULATION	GPCD
RFF	2.95	
Census	2.83	
PHS	279	

OTHERS -

175 - 275	GPCD	Consulting Engrs
100 - 93	" "	USPHS

DE FALCO - Regions must deal with peoples. We are a long way from the immediate problem. Some of the published figures should be [illegible] with the fields

JACK THOMAN -
140 gal/c/day national ave. (since 1939)

* APARTMENT LIVING LOWER g/c/d. figure - and may offset higher suburban figures -

MUST waste WATER TREATMENT BE HIGH PRICED?[*]

By

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ABSTRACT

Water treatment begins at the point of use, and the final treatment is provided at the point of discharge. Design criteria can become too stereotyped, resulting in more costly treatment practices. The waste stabilization pond is probably the most economical system of waste treatment for many of the smaller communities. However, as with all present-day treatment operations, much research and development is still needed.

Water is one of the necessities of life. Furthermore, it is one of the major resources in the United States. The distribution and use of water is controllable to some extent, but the reuse of water is dependent upon the resourcefulness of the present generation. The pollution of large amounts of water with smaller amounts of contaminants is an economic luxury which this nation cannot afford. It is recognized by most responsible people that the use of water is a privilege and that treatment of used water is a necessity. The degree of treatment may vary from place to place, but the cost of treatment represents a fee for using the water.

Merciless man must not turn the streams into poison for other users. Man must pay, but it need not be expensive.

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[*] A paper to be presented to the U. S. Public Health Service Conference on Water Resources, Region VII, Dallas, Texas, May 15-17, 1961.

If the majority of our future water supply is to be a mixture of pristine and adulterated waters, then water treatment must logically begin at the point of pollution and not at the water intake of some downstream user. This paper describes some of the reasons why domestic waste treatment need not necessarily be expensive. The ultimate objectives remain the same with regard to water treatment and use, i.e., it is not only desirable but necessary to destroy the pathogenic microorganisms and, in some manner, reduce the putrescible organic matter to carbon dioxide or otherwise inoffensive substances. The scientific aspects of the algal-bacterial commensalism (eating at the same table) system will be considered herein, but the emphasis will be placed on the development of the "art" of waste-water treatment by the use of waste stabilization ponds.

Engineering Apathy

Water quality control is an engineering problem but with roots in almost all the social and scientific disciplines. Engineers, as a professional group, pride themselves in being able to utilize these various disciplines to obtain one or more plausible solutions to an engineering problem. Once having developed possible answers, the professional engineer makes his decision on the basis of an economic evaluation. It is at this point in a water development study when an engineer searches his mind and conscience for all the knowledgeable facts. The figures are bared, and an honest appraisal is made. It is a rare case indeed when the engineer reaches a major decision on purely materialistic considerations.

Even as individuals, professional groups sometimes become engrossed in what are all too frequently described as technicalities. This is clearly demonstrated in the area of water and waste treatment. To this extent the American engineer has expended much effort on the use of power and extended the application of mechanical appurtenances, particularly in the field of water treatment. He has strived to perfect larger and more sophisticated systems. This, in itself, is not bad because the creation of things satisfies the innermost desires of most builders, and the engineer surely is a maker of things. For some engineers, dedicated to the field of water resources, there is the age-old desire and challenge to control the movement of water, to build large impoundments, and to construct impressive treatment facilities. All of these systems obviously are to be built on a river that has water of the highest purity and no historical connection with domestic or industrial use. Even if water has been used as a transporting medium for industrial and municipal wastes, it is still a challenge to design complicated systems satisfying the latest in experimental equipment. The temptation is great to erect mammoth air-compressor and air-dispersal systems which provide air in ever smaller bubbles, and to build biological treatment systems that are continually helping to reduce the mean flow through time. Such devices are economic necessities in some places but not in the majority of cases.

It is of considerable significance that through the centuries the definition of water purity has become more sophisticated. As the standard of living has increased, the criteria of purity have become more rigid and possibly more quantitative. In retrospect, the engineer as an individual may have become accustomed to recommending the "Park Avenue" variety of hardware and, in some ill-advised situations, completely ignoring the dictum that all plausible solutions to the water treatment problem must be considered before submitting a recommendation. A case in point is the small-town sewage treatment plant. In most cases the engineer knows full well that the operational control required of this "Park Avenue" treatment plant will not be forthcoming. As a matter of fact, in the past it has been difficult to obtain appropriate operating experience for the plants servicing the larger cities.

Has it been complete disregard for economic principles which has led the engineer to choose the sophisticated designs? The answer to this question is, "Probably not."

Historical Objectives

It has been customary for engineers to be content with developing more economical unit processes including primary sedimentation followed by aerobic biological treatment and the anaerobic digestion processes to stabilize the unoxidized solids.

The conventional treatment systems, for obvious economic reasons, have not been designed to recover significant amounts of nutrients in the waste water, these nutrients being primarily phosphorus and nitrogen compounds. The total nutrients in the near future may actually exceed ten million tons annually, and the next generation of engineers may very well be concerned with the problem of total nutrient recovery.

The historical treatment plant, for not always obvious reasons, has been designed to provide oxygen by mechanical means. The oxygen is utilized by bacterial masses in synthesizing more cells or oxidizing the organic matter for energy-conversion purposes. The mineralized effluent from such processes represents a considerable amount of fertilizer in the form of inorganic solids.

Unfortunately, it is at this stage in the historical treatment processes that the conventional system begins to break down. The putrescible material has been reduced to simple organic products, compounds of nitrogen, phosphorus, etc. It is not desirable to have this fertilizer in the water because in the presence of sunlight these nutrients will support a crop of microscopic plants. Yet this is exactly what happens. The low-energy materials which have been added to a stream as a result of domestic and industrial wastes are converted to high-energy forms through the process of photosynthesis. The aquatic flora in itself is not so seriously objectionable, but, in terms of hydraulic terminology, steady state conditions of growth are difficult to maintain. Sunlight, temperature, food, pH, and numerous other factors influence the harvest. The stream, after receiving the expensive and highly treated effluent, is subjected to a cyclic form of crop rotation. This is likely to be a particularly difficult problem in the future.

The tremendous fluctuations in algal blooms have not been experienced in all sections of the country because the deposits in stream beds have been periodically flushed out to the ocean, but, as the streams are more rigorously controlled by the construction of impoundments, this periodic flushing will not take place as often. This mode of water-resource control will tend to place new pressures on the engineer to examine the manner in which water and waste-water is usually treated.

A reservoir which receives a continuous steady supply of nutrients from an upstream source can eliminate these nutrients either through discharge via downstream releases or through the transfer of these nutrients to higher forms of life such as fish. If the fish are then removed, this represents a net loss to the lake. However, it must be pointed out that the base level of nutrients in a reservoir at any time in the future, regardless of whether the reservoir has been nearly emptied and then refilled with dilution water, will be greater than the initial base level. Also, the higher trophic levels, as represented by fish, are not considered to be primary consumers of nutrient as are the bacterial and algal systems.

The Ultimate in Waste Treatment

The most efficient use of the carbon, nitrogen, and phosphorus in conjunction with sunlight would be to convert these materials into usable food stuff or to put the water and nutrient on irrigable land. This approach is not new since it has been considered in Germany and in several investigations in this country. The scheme simply indicates that putrescible organic material and other materials, theoretically at least, can be transformed into a high-energy protein substance. By using algal-bacterial processes, it is possible to produce an amount of protein from one acre of domestic waste-water stabilization ponds equivalent to as much as fifty acres of irrigated cropland. The algae provide the oxygen for aerobic bacterial synthesis and oxidation. To complete the cycle, the algae utilize the carbon dioxide released by bacteria and obtain other trace nutrients to propagate their own species. The difficulty in this approach is the fact that the algal cells are very small, and they are difficult to remove from the liquid substrate.

Therefore, until it is possible to remove the algae and nutrient or the nutrient alone, the waste-water might as well be treated as economically as possible. Nutrient releases under present conditions will be about the same, and algae in the effluent from a waste-water treatment plant merely moves the algal system upstream a few miles.

Waste Stabilization Ponds.

Sewage oxidation ponds are not new. Sewage lagoons and oxidation ponds have been used in Texas for at least 40 years. Prior to this time the Germans and the Chinese used a form of waste stabilization ponds or sewage lagoons for treating waste and raising fish. Waste stabilization ponds is a term, for lack of a better definition, which describes a more recent engineering development of the earlier sewage lagoons.

Today most nations, and states in the United States utilize waste stabilization ponds as a means of treating domestic effluents. It is estimated that there are over 2,000 acres of pond surface in Texas and over 400 cells. Most of these are a secondary form of treatment. However, it has been reported that there are now more than 300 communities in the Missouri Basin which use stabilization ponds as the sole mode of treatment.[3] Waste stabilization ponds comprise over 10 per cent of the secondary type sewage treatment plants in the U. S.[5] and compare very favorably with trickling filters and activated sludge treatment methods. As shown in Table 1, the conventional biological systems on an economic basis cannot compare favorably with waste stabilization ponds when the population contributing to the treatment plant is relatively small. Even when a population concentration of 100,000 exists, the per capita costs are still much cheaper for the consumption of stabilization ponds.

Table 1. Per Capita Cost of Construction in 1913 Dollars for Treatment Plants in U. S. (a)

Population	Stabilization Ponds	Trickling (c) Filters	Trickling (b) Filters	Activated Sludge
100	3.05	27.24	17.19	16.00
1,000	1.69	8.57	9.02	8.80
10,000	0.94	2.70	4.73	5.00
100,000	0.52	0.85	2.48	2.70

(a) Data only relates contract cost, or about 80% of total first cost.
(b) U. S. Total.
(c) Without separate sludge digestion.

The operation and maintenance costs of a waste stabilization pond are so much lower than those which would be required for the trickling filter and activated sludge treatment systems that there is no justifiable comparison. Table 2 shows the estimated annual operation and maintenance cost for about 300 treatment plants.[6]

The annual operation and maintenance costs for the primary plants are roughly equal to the trickling filter These costs are roughly $1.40 per capita per year.

If it is assumed that the excess activated sludge stabilization pond in Austin, Texas can be prepared on an equal basis, the operation and maintenance costs are 25 cents per capita per year. At present the ponds are receiving the BOD from equivalent population of 50,000 people.

Table 2. Estimated Annual Operation and Maintenance Cost

Expected Annual Cost ($/cap.)				
Population	Primary Plants	Activated Sludge	Standard Rate Trickling Filter	High Rate Trickling Filter
100	----	9.20	-------	-------
1,000	2.67	3.51	3.52	4.57
10,000	1.41	1.88	1.31	1.36
100,000	0.91	1.21	0.75	0.73

Furthermore, it should be recalled that these stabilization ponds could very readily handle twice the present load. The estimated annual operation and maintenance costs for the activated sludge and trickling filter plants is at least 5 to 6 times the cost of keeping a pond system. It also should be pointed out that a great deal of dilution water must be pumped from the river and mixed with the excess activated sludge at the Austin plant. This is considered part of the operational costs in this particular plant and would not be a major factor in the normal waste stabilization pond system.

Sludge Stabilization Ponds

In 1954 the City of Austin, Texas, found itself in a typical sewage treatment predicament. The inadequate conventional activated sludge treatment plant was converted and expanded to the Biosorption process at a cost of $390,000.00. The plant provided continuous good results for the first time, but while the new process solved the operational problem for maintaining a satisfactory BOD in the effluent and the immediate loading of the main plant, it did not solve the excess sludge disposal problem.[7]

It was estimated that the capital cost of the digesters of adequate size for the 1954 load would be $750,000. The importance of this figure was that it did not include the cost of additional drying beds or a vacuum filter plant installation, nor provisions for future increases in load. Assuming there is a market in Austin for filtered and heat-dried sludge as fertilizer, which there probably isn't, there would still be a net loss of $8.00 to $15.00 per ton of sludge processed. The City of Houston reportedly sells their sludge for an average of $13.00 per ton but it costs them $21.00 per ton to vacuum filter it and process it for sale.

The decision was made at Austin to try the ponding system used by San Antonio for handling the excess solids. At San Antonio, Mitchell Lake with a surface area of about 700 acres has been receiving some digester supernatant, primary treated sewage and excess activated sludge for a long time. After considerable study, a 270-acre tract of land was purchased as a site for the sludge oxidation lake system. It is about two miles from the treatment plant and adjoins the Colorado River.

To date, three lake systems have been designed, constructed and put into operation. The capacities are 41, 65, and 85 acres.

The capital and operating costs are as follows:

Land-------------------------------$120,000.00
Construction (complete)------------ 455,000.00
Total Capital Costs----------------$575,000.00

Operational Costs------------------$ 12,500.00/yr.

It is estimated that the operating costs during 1958 when the ponds were not even loaded to capacity was $4.80 per ton on a dry weight basis.

This represents a substantial saving as compared to other types of treatment. Also, at this time there appears to be a fair market for the bait and larger forage fish which appear to thrive in the lakes.

There have been no serious problems in the operation. Embankments were graveled to prevent erosion, and a gasoline driven paddle wheel was mounted on a raft to disperse floating algal masses which sometimes accumulate in a corner as a result of wind action.

The following is an abstract of the 1960 Annual Report of the Sewage Treatment Plant, Austin, Texas, describing the ponds:

5-day BOD Total Pounds	3,818,505
Pounds per acre per day, Average	55
Pounds per acre per day, Maximum	165
Pounds per acre per day, Minimum	0
Suspended Solids, Total Pounds	5,292,549
Pounds per acre per day, Average	76
Total Flow into Lakes (M.G.)	
1. Excess Activated Sludge	100.7
2. Digester Overflow	4.9
3. River Water	4,483.7
Total Flow Out (M.G.) Estimated	2,877.3
5-Day BOD in Effluent (ppm) Average	17.2
5-Day BOD in Effluent (ppm) Maximum	42.0
5-Day BOD in Effluent (ppm) Minimum	1.2

It should be noted that the first lake (41 acres) received an average loading of 200 pounds of BOD per acre per day which represented 90% or more of the excess sludge production in 1958. This loading might cause some concern, but, by the addition of the new 85-acre and 65-acre lakes, there is sufficient lake capacity to dispose of twice the present sludge production.

A Ransom for Nutrients

One of the biggest problems in water quality control is that of excessive nutrients in the water. Domestic wastes add a considerable amount of phosphorus and nitrogen to the water. As a matter of fact, domestic sewage is a rich source of the nutrients generally required by phytoplankton. However, it is noteworthy to mention that domestic sewage does not really provide a balanced diet for microorganisms. There is an overabundance of phosphorus as compared to both carbon and nitrogen. The organic carbon is usually limited in the case of activated sludge. Generally, carbon is not limiting in the case of algae because adequate amounts of carbon are normally available in the form of alkalinity.

As a matter of interest, normal phosphorus removal in a sewage treatment plant ranges from 2% for primary treatment to an average of 23% for the plants employing biological treatment.[4]

The possibility of removing nutrients, particularly phosphorus, by select species of algae is also realistic. The work of Bogan and others have shown that it is possible to remove nearly all the phosphates very rapidly by algal cultures.[1] It was shown in this work that the phosphate concentration could be reduced from 20 or more mg/l to less than 5 mg/l in less than four hours. The algae were responsible in absorbing or aiding the coagulation of the phosphates where removal of large amounts of phosphates were involved. However, common metabolic conversion is the principal mechanism of removal when a typical waste stabilization pond is employed.

The algae in phosphorus removal operations serve two purposes. In one case, an abundance of cell production will naturally accumulate a greater amount of phosphorus. In the second case, the phosphate removal is dependent upon a high pH, and, if adequate lighting is available for an abundance of algal production, the pH is increased. This latter requirement creates somewhat of a paradox in actual waste stabilization pond operation because the light intensity in the deeper pond is not generally adequate for the production of maximum numbers of cells nor maximum pH maintenance. When the day comes that algae might be utilized for both waste treatment and phosphate recovery, a totally different design will be needed. This day may not be in the too far distant future. At the present, a choice must be made whether to remove the phosphorus by maximum algal production or to maintain only a sufficient algal population to provide adequate amounts of oxygen for the bacterial population. Fish are a less efficient means of nutrient removal but possibly adequate to serve the present needs. A source of revenue might also be found in fish for cat food, feed supplement, etc.

Simplicity of Design

Waste stabilization ponds are economical because ponds may be designed to provide treatment of any wastes that can be oxidized biologically. The engineer must always remember, however, that the water to be treated has been contaminated and will be esthetically unacceptable to the general public.

It is desirable that some form of pre-treatment of the waste be the rule rather than the exception. Screening, in general, and preferably grinding should be provided for domestic waste to remove unsightly floating material. This type of pre-treatment is also necessary for most industrial wastes.

Sufficient acreage should be obtained to prevent encroachment by residential subdivisions. If isolation cannot be obtained, additional volume should be added to the ponds, or sedimentation as a pre-treatment should be provided.

Ponds with sufficient storage usually exhibit an exceptionally high degree of coliform removal. In this respect, waste stabilization ponds may be used for providing a higher degree of treatment in combination with other types of treatment.

The principal factors affecting the design of stabilization ponds are light, temperature, waste characteristics, degree of isolation, and topographical features. If BOD reduction is the primary objective, it is not necessary to have maximum penetration of light. It is possible for anaerobic decomposition to take place in certain sections of the pond, namely at deeper levels, but this has no adverse effect on the overall performance as long as aerobic conditions prevail over the surface. In most cases, the oxidation reduction potential at the depths where there is no apparent dissolved oxygen will indicate an aerobic-type environment rather than a true anaerobic system. Temperature appears to be of considerable importance. Since the rate of biochemical oxidation is largely a function of the bacterial activity, pond requirements must be based on winter loading rates. However, excessively high temperatures during the summer may either produce an odor problem or an overproduction of algae.

There have been cases where the water temperatures have increased in very shallow ponds to the point where the algal population was severely restricted and anaerobic bacterial systems created a considerable odor problem. This situation can be remedied generally by maintaining a somewhat deeper pond level, five feet or more. This increase in depth during the summer represents a basic change in pond philosophy. This will permit higher summer loading rates and the pond temperature will be roughly the same as the mean annual temperature. Since surface aeration alone will probably not provide more than twelve to sixteen pounds of oxygen per acre per day, the algae must provide the remaining oxygen.

If color in the effluent is a problem, series operation is a necessity. A lower algae concentration and generally higher quality effluent will result from ponds constructed in series. If the first pond is receiving raw sewage, it should be larger than the remaining ponds or septic conditions will prevail. Although the shape of the ponds is usually determined by topography, it is necessary to eliminate all stagnant corners. All the dikes should be well constructed. The top of the dike should be wide enough for automobile traffic. Gravel placed on the inner slope has proven to be very effective where wave action presents a problem. Other more permanent forms of lining probably reduce maintenance but greatly increase the cost of the installation.

Multiple inlets and outlets in the first pond are highly desirable. In this connection, it is important to have the bottom of the pond cleared of brush and other material before filling.

Every precaution should be taken in the design to prevent the possible breeding of mosquitoes, collection of floating algal masses, stagnant areas, and pollution of ground water through porous formations. Bank control will help eliminate the mosquito problem. Agitation of stagnant areas will prevent scum formation. Finally, bentonite is frequently helpful in sealing the bottom of the ponds.

The Economic Balance

The measure commonly employed in totaling waste-water treatment is "BOD removal" from a municipal or an industrial source. This is not an ideal measure, since other yardsticks (color and nutrient, for example) may still prevent the use of water for other downstream purposes. In water-deficient areas, the color problem has not usually been considered a serious threat to quality. However, the immediate removal of readily putrescible material and the destruction of enteric organisms is of considerable importance in all areas of the country. Where there are a limited number of dollars available, the climatic conditions are favorable, and the geographical conditions permit, the engineer in all sincerity must consider the possibility of designing and using waste stabilization ponds. Except where land costs are excessively high and where population densities are much greater than are normally experienced in most sections of the United States, waste stabilization ponds are the least expensive of all the presently known forms of domestic waste treatment.

There are many problems which the engineer faces in the treatment of waste waters. As in all waste-treatment systems, the waste stabilization pond is not now nor should it be the ultimate answer for treating municipal and industrial wastes. At least twenty years of intensive research and development is required to answer problems which arise in the field.

Conclusions

1. Waste stabilization ponds may be designed and operated economically under a wide variety of conditions.

2. If necessary, a waste stabilization pond may be designed to accomplish all of the functions normally provided by partial and complete sewage treatment plants.

3. In addition to a nominal amount of light, temperature is An (the most) important factor. Excessively high temperatures and shallow depths can produce nuisance problems as well as low temperature operations. When H_2O temp raised [illegible]

4. Although waste stabilization ponds are the least expensive means of treating domestic waste today, the following research and development suggestions and questions are submitted.

   a. Field studies should be made to determine the effectiveness of mechanical aerators in the first of a series of stabilization ponds. Certain efficient low-lift pumps and cavitators may help to develop an extremely active biological floc and thereby assist decomposition of the putrescible waste.

   b. The effectiveness of fish farming as a means of nutrient removal should be more thoroughly investigated. Not to efficient.

   c. Additional algal and nutrient removal schemes should be investigated.

   d. Specific information is needed to determine the role of oxidation-reduction potentials in biologically active systems throughout the waste stabilization ponds.

e. Considering various temperatures, what portion of the biochemical oxygen demand of an organic waste is satisfied by photosynthetic oxygenation? What fractions of the BOD are satisfied by oxygen from chemical sources and from the atmosphere?

f. What is the effect of temperature as the sole variable on waste stabilization ponds?

g. Fundamental studies should yield considerable information regarding the cycling effect of algal cell production and variation in species that is so obvious but difficult to explain.

h. It is desirable to know the relationships between the pond and ambient temperatures as they affect the growth characteristics of the algae.

i. What is the effective storage capacity of the bottom sediments as regards nitrogen and phosphorus?

j. Is there a health problem associated with the use of waste stabilization ponds for raising bait and forage fish?

k. In the larger lakes, what health significance might be associated with the use of these ponds as a duck and other wild life refuge?

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NOTES

TREATMENT MUST BE AT THE POINT OF DISCHARGE.

STREAM CAN NOT STAND THE NUTRIENTS.

Now about
61000 Lagoons in Mo. Valley Area. Odor is not
a problem. Mosquitoes are not a problem.

Region VII looking for info on need for dilution thru-
3rd treatment by expanding lagoons to a series
type and remove the fish produced. *

Phosphorus
Remove "P" by addit section to lagoons.

MUST STREAM QUALITY BE MAINTAINED?

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My first reaction to the question which is the subject of this discussion was that I could dispose of it in short order with a simple, unequivocal "Yes."

On second thought, however, faint doubts started to arise regarding the adequacy of such a simple, straightforward answer. When I considered means of resolving those first faint doubts not only did they refuse to vanish but they actually grew bigger and stronger and in turn produced a brood of lusty offspring. Finally I was faced with such an array of clamoring doubts that I was driven to the reluctant conclusion that here was a question that required strenuous mental effort. After undergoing the necessary, even though distasteful, mental effort I have come, with mixed emotions, to the inevitable conclusion that here is a question that I, alone, cannot answer. The mixed emotions include both amazement and relief. The amazement derives from the realization that, despite some thirty years in this business of stream sanitation, I cannot glibly answer

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all the questions involved in arriving at a sound decision regarding the need for maintaining water quality. The relief stems from the realization that I, alone, do not have to assume the awesome responsibility for the ultimate decision.

As a matter of fact, neither this group, as well informed and competent as you are, nor the Public Health Service, with its weighty responsibilities in the field, can make this decision. It is a decision which, under our form of government, the public must make.

We cannot, however, lightly dismiss all of our responsibilities in this matter by shifting them to the broad shoulders of the public. We must make up our own minds regarding what we believe about maintenance of water quality and provide the public with an honest and sound basis to assist him in reaching his decision. Which brings us full cycle back to our starting point of having to face up to a very complex and challenging question. Although I am not, and I am quite sure you are not, vain enough to believe that we can come up with complete and final answers here and now, I do believe that we can make some useful progress toward the answers we need.

Those who designed this program made an already difficult problem even more difficult by a ground rule with which they sought to anchor us speakers to terra firma and to prevent us from soaring into orbit in the stratosphere. This ground rule states "Remember that you are talking to professionals, not laymen, and minimize generalities and philosophy as much as possible." The qualification "minimize - as much as possible" provides a loophole of which I propose to take, indeed I must take, full advantage. Otherwise, our problem would be insoluble. I have a sneaking, though unconfirmed, suspicion that the program designers hopefully may have believed that all the subjects they propounded might be dealt with exclusively by an engineering approach, supported by incontestable facts and figures. I submit that the subject represented by the question "Must Water Quality Be Maintained?" can be resolved only by venturing into the philosophical realms of emotions and of morals, as well as into the more prosaic field of engineering. Only a small portion of the answers to this question will come from manipulation of the slide rule. The major portion of the answers ultimately will come from the secret and poorly understood workings of the mind of that aggregate man, the public, and will be influenced by his emotions and, we hope, by his morals, when he deposits his decision in the ballot box.

In order to come to grips with our problem, which I already have delayed as long as I decently can, we must reach some agreement on definitions and limits of the subject matter. For example, what does the first word "must" imply. Among other things Webster says it means "obliged by logical necessity" and "morally required." Both of these are acceptable meanings for our purpose, but they do not go quite far enough. We must, and we shall attempt to, determine whether "must" means absolutely and without exception, or does it allow some latitude for the exercise of judgment? Also, it fails to take the time element into account. Does it imply that we must start maintenance now, or does it permit the flexibility which will allow us to justify postponement of action on an anticipated need to some future date when the potential need becomes an actuality?

Likewise Webster is of some help on "maintain", but again his definition, "To hold or keep in any particular state or condition," does not go nearly far enough. What state or condition must we hold? Must it be the natural state, the present polluted state, or some future improved state? If it is to be an improved state where do we draw the line regarding the degree of improvement?

I trust that we need not to go to Webster for a definition of water, but his definitions of quality as "Natural superiority in kind" and "Excellence of character" fit right in with the state in which we would prefer to keep our waters. Unfortunately, we must temper this highly desirable state of affairs with considerations of practicality of achievement.

Let's decide just what we want to talk about so that we can confine our discussion within reasonable limits. I suggest as our objective the development of such guidelines as we can agree upon which will best serve our attempts to plan water quality maintenance programs. The aim of such planning should be to assure, within limits of available quantity, water of such quality at such places and such times as will best serve the public welfare.

The objective of water planning frequently is expressed as development of a plan which will assure maximum development of the region involved. I am not sure just what is implied by "maximum development" but I am inclined to think of it in terms of the most people that the area will support. I am not sure that the most people is what we really want. After all, the maximum development of a land area in terms of number of people is represented by our city slums. Obviously this is not a type of situation that we want, for most of our major cities, aided by both state and Federal governments, are spending huge sums of money to dismantle slum areas and distribute the overcrowded populations to other areas where they have more room and more healthful and pleasant living conditions. By analogy, the greatest possible number of people using our streams would reduce the streams to dead, lifeless, and stinking sources of contagion with minimum usefulness and no aesthetic appeal. I am quite sure that this type of maximum development neither is wanted nor will be tolerated.

It is for this reason that I prefer to state our objective as maximum service to the public welfare rather than as maximum development of an area. And it is around the problem of what water uses truly are best for the public welfare that all our vexations, our doubts, and our soul searching center. Is it possible that we are assuming too much responsibility in this area? Do we, as public health engineers, feel obliged in our water planning to evaluate all of the innumerable and highly complex factors that influence the public welfare? If so, we are setting ourselves an impossible task, for we simply are not equipped with either all of the knowledge or all of the wisdom necessary for the task. We are presumptous if we assume that we are so equipped. When we recognize this we can begin to think about the other disciplines that we must call on to work with us and assist us in reaching our decisions. I am sure we shall feel more comfortable about our problem when we reach this state of maturity. Even when we thus resolve some portion of our concern we still are faced with the fact that there exist within our own field of competence considerable areas in which we yet have much to learn. If there were no such areas there would be little or no need for the professional public health engineer and no necessity for the exercise of judgment. If we knew all we needed to know someone long ago would have produced a handbook, cookbook style, which anyone could follow to produce a sound water quality management plan. We soon would be out of work.

In seeking our guidelines let's start with such generally accepted precedents as we already have before we soar into the realm of speculation.

Probably our soundest precedent is that of riparian rights. In this country the riparian rights doctrine was borrowed from the

English system of jurisprudence, where the doctrine had been in effect for many, many decades. This doctrine is law in about two-thirds of our states. It assures all owners of property adjacent to a stream the right to use of the natural undiminished flow of the stream with its natural quality unimpaired by upstream use.

The other third of our states employ the doctrine of prior appropriation. This vests the right of beneficial consumptive use of water quantity in the user who first establishes his right to such use. This type of use, however, is of a usufructuary character. Again turning to Webster we find that usufructuary means having or possessing a usufruct, which is of little help. Tracking down usufruct, however, we find that this means "the right of using -- the fruits -- of an estate or other thing belonging to another without impairing the substance." To me, this implies that the right to quantitative use does not include permission to alter the natural quality of any water of the stream which is not used or which is used and returned to the stream.

Thus we have a clear, legal mandate from the public, through our laws on water rights, that the natural quality of our streams is to be maintained. I am not aware that either of the two doctrines awards the user of water the right to impair the quality of the stream provided he decides that it is too costly for him to maintain the natural quality.

The legal mandate is clearly supported by the emotional attitude of the public. Man has an instinctive affinity for water. His very body is more than ninety percent of the stuff. The biologists tell us that life itself originated in the sea, and that somewhere along the evolutionary chain our ancestors emerged from their watery home to begin their struggle for existence on dry land. Man always has been restricted in his travels by the need for an ever present source of drinking water to maintain life, or else he has had to carry his drinking water with him. Before he was able to transport substantial quantities of water for considerable distances he lived, as a matter of necessity and of convenience, very close to a body of water. All of these associations appear to have left their imprint in that recess of the mind of Man in which his instinct resides. Man instinctively loves water. Even as a baby there are few pleasures that he enjoys more than his daily bath. As a child some of his happiest moments are spent wading in water, with or without shoes, splashing in it, and sailing toy boats on it. As an adult, water has a tremendous appeal when he seeks the recreation that is so essential to his welfare. He loves to swim in and under it, glide over it in a boat or on skiis, take fish from it, and just sit and look at it. On vacation he will travel hundreds of miles to enjoy his favorite body of water, be it ocean, lake, or turbulent mountain stream. His first requirement in considering a suitable location for a summer cottage of his own usually is that it be within sight of a body of water. But the sense of pleasure that he derives from association with clear, clean, sparkling water gives way to frustration, disgust, even rage, if the water exhibits observable effects of pollution.

I use the word "observable" advisedly, for the public judges the condition of streams most often by what they can see and smell. Occasionally they may condemn a stream by the taste of their drinking water, but more often they are apt to blame the poor water plant operator for putting too much of "that chlorine" in the treated water. But when they see feces, condoms, toilet paper, rags, grease, and the infinite variety of other solids discharged from sewers floating on or bobbing in a stream, they know that stream is polluted.

When they see excessively muddy or unnaturally colored water, they conclude that the stream is polluted. When a stream carries an excessive organic load which imparts that typical grey, dull, lifeless appearance the public knows it is polluted. When they smell the rotten egg odor of hydrogen sulfide evolved from sludge deposits or from a septic stream they are convinced that pollution is the cause. When they no longer can catch fish, or if their catch consists of carp or other scavengers and does not include game fish, they blame pollution. And I am not aware of many things in this life that can arouse such public hue and cry as the sight of a stream and its banks littered with dead and decaying fish. Even those who are not fishermen become indignant. Perhaps the uproar is aroused by the loss of a few hundred pounds of meat, but I suspect that more probably it results from revulsion at the visual evidence that the stream is sick with pollution.

These, then, are the sensible evidences of pollution which we must control. I am convinced that we have a mandate from the public, based in large degree on emotions, to keep our streams from looking and smelling polluted. Unless we maintain the waters of our streams in some semblance of their natural appearance the public will give us very little credit for our water quality control efforts, no matter what our success in controlling effects of unseen pollution may be. If the public frequently sees or smells the effects of stream pollution there will be very little incentive for them to continue to support water quality control programs.

The emotions which are involved in the public's reactions to what they can see and smell have led to legal means of protection against generally unpleasant conditions which arouse those emotions. This protection is provided by our ordinances on nuisances. These ordinances assure the individual that he does not have to put up with unduly unpleasant sights, odors, noises, and a multitude of other conditions to which his senses and emotions react adversely. The general principle that no one has a right to impose a nuisance on someone else has been accepted without question by those who have responsibilities for stream pollution control. Everyone in this business agrees that no nuisance shall result from stream pollution. Even those who reach the reluctant conclusion that economics dictate that certain streams must be abandoned to waste disposal insist that such use shall not result in production of nuisances, regardless of the cost of prevention. This insistence is reflected in the stream pollution control laws or regulations of practically every state.

The portions of the codes involving nuisances reflect major concern over prevention of odor nuisances, since most of them specify maintenance of some minimum dissolved oxygen content, low though it may be.

Another principal firmly established by pollution control agencies also is based on the public's emotional reactions to nuisances. This principal is the almost universal agreement that all domestic sewage should be subjected to a minimum of primary treatment. Many state pollution control agencies also require that industrial wastes be subjected to equivalent treatment, which basicly involves the removal of floating and settleable solids. Why do our control agencies generally agree on these requirements? We know that primary treatment accomplishes very little in the reduction of the unseen effects of pollution. The primary sewage plant effluent contains 60 to 75 percent of the initial biochemical oxygen demand, 30 to 60 percent of the suspended solids, and 25 to 75 percent of the pathogenic bacteria. I consider the relatively small fractions removed as a minor accomplishment at best. It would be interesting to know how many primary treatment plants have solved dissolved oxygen problems. I suspect that the number of those which have accomplished this would be a very small percentage of the total that have been built. The usual primary sewage plant turns loose into the receiving stream at least one-half, and probably more, of the pathogenic bacteria in the raw sewage. This residue presents a health hazard to all who use the water downstream for recreation. My own reaction is that I would have little, if any, more hesitation in swimming in a stream carrying raw sewage than in one carrying a primary effluent. I would not swim in either, and I do not feel comfortable boating on either.

In spite of the deficiencies of primary treatment we generally agree that it must be provided for all sewage and many industrial wastes, regardless of cost. I am convinced we have agreed to this requirement because it does control those things which the public can see and smell. The floating solids which offend the eyes and the suspended solids which produce sludge banks to offend the nose are controlled.

The benefits of preventing these offenses certainly are intangible ones to which no dollar and cents value presently can be attached. We accept the requirement of primary treatment on such an intangible basis without bothering to attempt a balance of costs against monetary benefits. Why, then, do we become so concerned over balancing costs against monetary benefits when we are dealing with the unseen effects of pollution, such as the hazardous billions of pathogenic organisms which escape from primary sewage treatment plants, or the dissolved organic solids in industrial wastes which may deplete the dissolved oxygen below levels that will support a balanced fish population? There appears to be a degree of inconsistency here, which may be one of the reasons for some of our soul searching over how much waste treatment we should recommend.

I trust we can agree at this point that we have legal support both in our water rights laws for seeking high degrees of waste treatment, and in our nuisance ordinances for essentially complete control of observable effects of pollution. It is my opinion that the public's affinity for water and their reaction, emotional if you please, to evidences of defilement by pollution have played an important part in the evolution of these laws.

Thus far we have not approached our problem from the standpoint of morals. It should be easy, it appears to me, to reach agreement on this phase of the problem. Either it is right for a municipality or an industry to discharge pollutional material which imposes on downstream users of water or it is wrong. I see little real difference between such discharge of refuse and that of pitching my garbage across the fence into my neighbor's yard as the easiest way to dispose of it, or of allowing my underground sewage disposal field to spew sewage across my neighbor's property line because it would cost me too much to repair it. I spend money to avoid defiling my neighbor's property. I would consider it wrong, and would be nagged by a very guilty conscience, if I did otherwise. Should the conscience of the corporation, be it municipal or industrial, be any less acute? Unfortunately the corporate conscience frequently appears to be much less acute, and at times even non-existent. Fortunately our society has laws to deal with its members who have no consciences. When persuasion fails the law should be brought into play to make those do right who otherwise would do wrong, or at least to stop them from doing wrong.

Perhaps you think I have talked too much about the law in my preceding discussions. I have intentionally emphasized the legal factors. I think we sanitary engineers and economists are prone to become so intent on our engineering and economic calculations, evaluations, and judgments that we are apt to forget the intent of our laws and to substitute instead our own opinions as guiding principles. Perhaps our opinions are more valid in this particular field than are the laws of our land. If so, ultimately, the laws will be changed to reflect our opinions. Until that time, I consider it incumbent on us to bring our recommendations on waste disposal into line with the intent of our laws.

In patterning our recommendations after the intent of our laws we must follow the interpretations of the laws evolved by the courts. The judicial interpretation of the doctrine of riparian rights, for example, appears to be leaning in the direction of reasonable use that will not interfere unduly with downstream uses, rather than demanding strictly that there be absolutely no interference with such uses. This trend immediately brings us face to face with decisions regarding how much interferences with downstream uses will we permit. Let's see what precedents we have to guide us in these decisions. There may not be all we need, but at least they can serve as a starting point.

Our best precedents probably are those used as guides or as requirements of state water pollution control agencies. I had occasion fairly recently to review state practices in this matter, and found that there is more agreement among the states on certain factors than you might expect. Almost all who have produced official statements on requirements prohibit floating solids and suspended solids that will cause sludge banks. About two-thirds of the states have official requirements or are members of interstate groups which seek to maintain monthly average MPN's of coliform organisms of less than 5,000 per 100 ml for both sources of domestic water supply, and for general recreation, such as fishing and boating. About the same number specify average MPN's of less than 1,000 per 100 ml for swimming and other water sports involving body contact. Again, the same two-thirds of the states seek to maintain average dissolved oxygen concentrations of at least 5 mg/l. Most of the states recognize the Public Health Service drinking water standards both for finished drinking water in toto and for streams as regards those numerous constituents, principally inorganic in nature, which are not eliminated or controlled by conventional water treatment methods. Finally, practically all states recognize the public's insistence that fish be protected. This recognition is reflected in requirements that constituents harmful to fish and other aquatic life be held below toxic or lethal limits. These combined requirements, on which at least a majority of the state pollution control agencies agree, furnish a substantial base on which to build in reaching decisions regarding the degree of waste treatment needed to maintain water quality. I judge that application of these requirements, plus others which are not covered but may be selected at comparable levels, will assure maintenance of water quality which will serve the public welfare.

Thus far I have not touched on water uses as a basis for determining needed water quality. I am sure I do not even need to suggest to this group that water uses must be considered. If there is no use of a particular stream there is little justification for concern over water quality. I maintain, however, that there are few streams in this country which are so isolated that they cannot be reached by car or by boat for fishing and other aquatic recreation. Streams protected for fish and other aquatic life, and for recreation, will have water of a quality which will meet the needs of most other uses to which they may be put. Even if we can prove now that a stream, or a portion of a stream is inaccessible, how can we say that fifty years from now, or within whatever period we select for planning, the same stream still will be inaccessible? While we may not insist on immediate protection of an isolated stream, in letting the bars down we must make it clear that this is a temporary expedient only and the bars will go up again as soon as accessibility to the stream may be imminent.

Many years ago our progenitors in sanitary engineering propounded an engaging proposition to which those responsible for sources of wastes immediately and enthusiastically agreed, and unswervingly have supported since that time. This proposition is that all streams should be used, where needed, for waste disposal up to the maximum assimilative capacities of the streams. In the beginning of my professional career I subscribed to that view and spent a great deal of time sampling, analyzing, and computing to the first or second decimal just what the assimilative capacities of streams were. I do not deny that I found this entrancing. Gradually over the years, however, I have become disenchanted with that philosophy. I cannot pinpoint my reasons for this disenchantment. Perhaps the one factor, more than any other, which has changed my viewpoint has been my realization, gradual at first but finally overwhelming, that we are steadily losing the battle against stream pollution. Perhaps I have associated an undeniable result with the wrong cause, but I cannot help but believe that the philosophy of maximum use of assimilative capacity has been one of the major stumbling blocks to effective stream pollution control. At least twenty years ago I heard Dr. Abel Wolman expound the philosophy that we should obtain all of the waste treatment that we could within economic limits. At that time such a thought was heresy. Yet last December in our Nation's capitol a substantial sector of the National Conference on Water Pollution agreed in principle with Dr. Wolman's earlier stand. Please note such panel conclusions as:

1. "The users of water do not have an inherent right to pollute";
2. "Users of public waters have a responsibility for returning them as clean as is technically possible";
3. "We recommend that the conference express its conviction that the goal of pollution abatement

3. is to protect and enhance the capacity of the water resource to serve the widest possible range of human needs, and that this goal can be approached only by accepting the positive policy of keeping waters as clean as possible, as opposed to the negative policy of attempting to use the full capacity of water for waste disposal."

It appears to me that every avenue of approach that I have taken in seeking an answer to the question "Must We Maintain Water Quality?" has led to the same conclusion, that we must maintain water quality at a high level indeed. These approaches have included consideration of our basic water rights and nuisance ordinances, the public's emotional involvement and rights in the matter, the rights and wrongs, or morals, of the problem, the requirements of state pollution control agencies with long years of experience back of them, and finally the latest expression of opinion of a substantial segment of the profession which is concerned with water quality and the effects of wastes thereon.

Against this impressive array of affirmative answers I am aware of only one negative answer that may be advanced. That is the common, inevitable defense of those who oppose corrective measures that "We cannot afford waste treatment." My reply is that I have seen a lot of municipal and industrial waste treatment plants in my day and I am not aware of a single town or industry that has been driven into bankruptcy by having to finance waste treatment facilities. I do know of two small pulp and paper mills that reached the final decision to close down at the times when pressure was brought on them to provide waste treatment. Both of these were marginal operations, at best, with daily capacities of 80 and 120 tons of paper, which are small mills indeed. I am sure that many economic factors, exclusive of the cost of waste treatment but including dwindling supplies of pulpwood, entered into the decisions to close. While we must sympathize with the limited numbers of employees that lost their jobs, I cannot believe that such marginal plants contributed substantially to the welfare of the communities involved.

I admit that I did not know where I was headed when I started preparing this discussion. Instead of attempting to guide my arguments I have tried to let them lead me to a conclusion. Probably the rambling nature of my discussion reflects this groping. In any event, I believe it has led me to a more honest and sincere conclusion than I would have reached if I had formed a preconceived answer. My first reaction that a simple, unequivocal "Yes" was the only answer needed has been modified somewhat, but I still believe that a positive answer, with explanations and possibly a few exceptions to prove the rule, is the proper answer.

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Principles and Policies for the Evaluation and Reimbursement of Water Supply and Pollution Abatement Benefits from Federal Water Storage Projects

Introduction

This paper deals with the problems associated with evaluating and paying for the benefits derived from the use of water stored in Federal reservoirs for those purposes which are the concern of the Public Health Service. These are municipal and industrial water supply, and water pollution abatement by means of dilution through augmentation of low river flows. These purposes are hereafter called simply "water supply" and "dilution" or "low flow augmentation", as the case may be. The paper is confined to a discussion of the principles and policy issues involved. If and when these principles and policies are agreed to, it will be desirable to prepare more detailed procedural guides for their effectuation, but no attempt has been made herein to delineate such procedures.

As a basis for the discussion of these problems, it is desirable to make clear certain tenets or concepts on which the discussion has been based. These are:

1. Primary effort in pollution abatement should be toward the reduction or elimination of polluting wastes at the source, by means of waste treatment plants or other means.
2. Dilution is not a substitute for waste removal, but should be looked upon, rather as a supplement to a program of treatment and of ultimate removal. In the latter sense, provision of dilution water should be considered a secondary defense, an interim measure, to be resorted to on a temporary basis pending the time when better treatment methods can be developed.

3. The costs of waste treatment or removal should rest first with those producing the wastes, but, beyond this, the costs of storing dilution water producing widespread benefits should be non-reimbursable.
4. In providing storage for a water supply, the necessity of providing additional water for the dilution of the resulting treated waste effluents should be recognized.
5. In developing Federal reservoir sites, every effort should be made to conserve their full potentialities through development of optimum storage capacity.

While the measurement of benefits usually enters into the formula for determining the costs to be assessed against or allocated to the various purposes of a multiple purpose Federal reservoir project, the actual measurement and evaluation of the benefits themselves is a separate problem from that of deciding who should pay the costs of providing them. The two problems are dealt with separately in the following two sections.

Section I

Criteria for Assigning Water Supply and Pollution Abatement Benefits to Federal Storage Reservoir Projects as a Basis for Determining Reimbursement Policy.

(a) Water Supply. The basis for including water supply storage in Federal projects, and the requirements for the reimbursement of the costs thereof, are specifically prescribed in P. L. 500 - 85th Congress, and need no further elaboration here.

(b) Pollution Abatement. Decisions regarding the reimbursement policy to be followed in dealing with pollution abatement benefits resulting from releases of water stored in Federal reservoirs are complicated by questions of public policy concerning the use of dilution as a means of abating pollution. Two categories of benefits are involved; incidental benefits, and planned benefits.

1. Incidental benefits. When low stream flow augmentation is produced as a result of the operation of a Federal project for other purposes, such as flood control, navigation, or municipal water supply, an incidental improvement in the quality of the waters of the stream usually takes place. This improvement may be due to the dilution of wastes or other pollutants which the stream carries, to an increase in the dissolved oxygen of the stream, or perhaps to a lowering of its temperature. Detriments may also occur, as when oxygen deficient water is released from the bottom levels of reservoirs. While these benefits are generally not planned for in the design of the project, and usually do not enter into the computations of benefit-cost ratios, they are nevertheless very real and should in some fashion be credited to, or in the case of detriments, charged against, the project. This is usually done by means of a separate discussion or presentation in the project report, including a monetary evaluation wherever this is possible. Under the circumstances described, it appears entirely proper to credit the Federal project on a non-reimbursable basis with these incidental pollution abatement benefits, even where the improvement in stream quality results in a windfall benefit to those causing pollution in the stream by making it possible for them to postpone construction of treatment works which would otherwise be required. One caution needs to be raised regarding such cases, however. Because of population increase, economic growth, or changes in stream quality standards

resulting from adoption of new sociological or environmental objectives, such windfall benefits should never be looked upon as continuing on a permanent basis. Their evaluation should be based upon the timing of future stream quality requirements as determined by the best possible projections of probable future demands upon the stream, and the duration of the benefits and the corresponding credits to the Federal project should be limited accordingly.

2. Planned benefits. In addition to the situation described above, improvement in stream quality through release of stored water may be specifically provided for in planning a water storage project. At the present time, no general authorization exists for the inclusion of this purpose in the design of Federal projects, but in several instances it has been specifically included in the authorization of individual projects, and studies now underway are recognizing this potentiality. It is expected that such authorizations may increase in the future, and the problem of assigning responsibility for meeting the costs of providing such benefits therefore takes on added significance.

The determination of reimbursement policy with respect to stream quality improvement benefits produced under the planned conditions just described is much more complex than in the case of incidental benefits. At issue is the question of the degree to which non-reimbursable Federal expenditures, that is, contributions by the nation at large, are justified for this purpose, in relation to expenditures which should be made by non-Federal interests for waste treatment works or other pollution abatement measures available to them in the first place. Specifically, the question is that of determining the level of waste treatment which pollutors should be expected or required to provide, before pollution abatement by dilution at Federal expense may be considered justified.

Said in another way, the determination of the justifiable degree of planned Federal participation in stream quality improvement endeavors, through low flow augmentation, requires first a determination of the amounts, kinds, and degrees of concentration of those substances which may properly be allowed to be discharged into a river, and the degree of dilution of these wastes required after treatment to maintain adequate water quality, as determined by appropriate authority.

Determination of Degree of Treatment Required Before Dilution is Warranted

A rational approach to this problem is provided if it is recognized that the waters of rivers and lakes are generally considered to lie within the public domain, and that they may be withdrawn for use only with the permission of the particular governmental agency, usually the State, having jurisdiction in each case. This is true under both the riparian rights, or reasonable use, doctrine and the prior appropriation doctrine. Under the reasonable use doctrine, the public has broad general rights in the waters of a stream, but the owners of property abutting the stream have the right to the reasonable use of the waters. Except for such beneficial consumptive uses as drinking, stock watering, lawn watering, etc., however, each riparian owner must, after use, allow the stream to flow undiminished in quantity or quality to the next user downstream, unless he is legally authorized to do otherwise. The prior rights doctrine provides for allocation of waters for beneficial consumptive uses but does not permit the user to discharge indiscriminately polluted waters back to the stream.

The public has broad interests in most streams with respect to sources of water supply, fish and wildlife resources, recreational values, and esthetic and environmental influences. An additional point to bear in mind is that, except for water consumed through evaporation and transpiration in connection with irrigation usage, and the very small amounts of water actually consumed by people and animals, withdrawn waters are largely returned to the river after use. Because of this latter fact, withdrawn water should preferably be looked upon as a service facility rather than as a commodity, as has heretofore generally been the case.

As a service facility, withdrawn water is used mostly as a solvent, cleanser, transporter or coolant, to carry away sewage and other waste products, dirt and grime, and heat, following which, because there is nowhere else to dispose of it, most of it is returned to the public domain in a lake or river, usually with most of the substances it was required to transport left in it. Viewed in this light, the service which the water user receives is essentially that normally provided by a rental facility. The rental price, in the case of water, of course, is the cost of the facilities required to withdraw, use, treat and return it. Under these circumstances, it is only proper that the rentor, at his own expense, should remove the transported commodities from the vehicle and otherwise make it suitable for the next user, before returning it, or compensate the owner (the public) for the cost of such removal. This is particularly true where the transported materials are obnoxious. This principle is entirely in keeping with the water rights doctrines under which the waters of the U. S. are managed.

During the earlier period in the nation's history when population was less dense, there was little recognized and accepted stream damage, and disposal of wastes into streams, in many instances, did not conflict seriously with other users. Today, with increasing congestion, close proximity of uses and users, and almost universal use of water for flushing away wastes, the discharge of large quantities of wastes into streams impairs their quality to the detriment of both downstream users and the general public. Under these conditions, the use of a stream as a vehicle for the disposal of sewage or other wastes is contrary to the public interest and the doctrines of water use.

Unfortunately, under current practices and within the limits of existing technical knowledge and the presently accepted limits of available economic resources, water is the cheapest convenient, generally accepted, means of transporting and handling sewage and some other offensive or detrimental wastes. Thus, with some small scale exceptions, the discharge of waste waters into public water bodies is at the present time the only practicable method of disposing of them. Under these circumstances it is obvious that water users, if they are to meet their obligations to each other and to the general public, must minimize the adverse affects of presently accepted waste disposal practices by treating their wastes, before discharging them into streams, in such manner as to remove as much of the detrimental substances which they contain as possible. The provision of water at national expense for the dilution of wastes, as a means of reducing stream damage, in lieu of proper waste treatment, is, under this premise, not only contrary to public policy, but constitutes a subsidy to the pollutor, and should, therefore, not be condoned or proposed. This general principle has been clearly enunciated in the testimony of Public Health Service officials before Congressional committees.*

Acceptance of the foregoing premise requires that "proper treatment" be defined. It is, of course, not possible, at any presently acceptable economic cost, to remove all polluting substances from used water. However, in the case of domestic sewage and of industrial wastes of a similar organic nature, a combination of primary and secondary treatment can, at quite reasonable cost, remove, on an average, at least 80% of the oxygen demanding organic wastes. Lagoons or "polishing ponds" and other treatment processes can, where necessary, further reduce the BOD remaining in secondary treatment plant effluents at additional cost. It would appear, therefore, that a minimum of secondary treatment or its equivalent is not an unreasonable prerequisite for crediting non-reimbursable pollution abatement benefits to Federal water storage projects. Similarly, with some other types of industrial pollutants, process improvements, treatment, impoundment or other processes can substantially reduce the amount of polluting material allowed to enter a stream. Only after all practical treatment measures have been applied, such as the above, should non-reimbursable pollution abatement benefits from low flow augmentation be credited to Federal projects. On this point, it should be noted that these levels of required treatment conform to the conclusions reached at the National Water Pollution Conference in Washington in December 1960, that "the objective of pollution abatement measures should be to keep national water bodies as clean as possible rather than to attempt to use the full capacity of water for waste assimilation", as heretofore advocated.

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* Statement of Assistant Surgeon General Mark Hollis before the Senate Committee on Public Works:

> ". . . in line with the Federal Water Pollution Control Act, pollution abatement should be regarded a primary responsibility of State and local interests. We, therefore, suggest that the record be clear that low flow augmentation should not be used as a substitute for sewage treatment works required by State authority or contemplated in comprehensive pollution control plans prepared under the Federal act. However, it is often difficult even with the best known treatment practices to preserve quality of water in streams suitable for normal re-use purposes during periods of minimum flows. Augmentation of low flows during such periods would be highly beneficial . . ."

In some situations and with some classes of pollutants, no methods of treatment are at this time available at any reasonable cost. Examples are the plant nutrients remaining in sewage after treatment, certain persistent industrial chemicals, acid mine drainage, heat, and salts dissolved from natural deposits. To be sure, a procedure can be instituted for reducing or preventing some of these substances from entering a stream in some instances, but in many cases no economical corrective measures have yet been devised. Furthermore, a considerable part of the nation is dependent for its economic wellbeing upon industrial establishments that produce wastes, such as these, which, at the present time, are difficult or impossible to treat at economical costs. Under the latter circumstances, sound judgment should be applied to avoid an unreasonable insistence on the elimination of such wastes to the economic detriment of the community. In most of the foregoing situations, the planned dilution of the wastes involved, at general public expense, appears proper pending the development of economical methods of preventing or treating them.

In applying the above policy, it should, of course, be made certain that in no case is the pollutor thereby permitted to escape his responsibility where treatment or control is feasible. Neither should any pollutor be allowed to postpone provision of treatment facilities, when treatment is or becomes possible, because of the improvement in river water quality resulting from such planned low flow augmentation.

It is frequently argued that even where treatment is economically and technically feasible, dilution could be substituted for such treatment if this is cheaper and if, at the same time, damage to the stream is in all respects satisfactorily prevented. Under these circumstances, the cost of providing the dilution water should, of course, be met by the pollutor, because he is thereby absolved from the necessity of constructing treatment facilities which he should, or would, otherwise have had to construct. Generally speaking, however, substitution of dilution for treatment is considered contrary to public policy because of possible dangers to health and damages to esthetic and other public values associated with the use of a river for disposal of raw or partially treated wastes. Where permitted, it should certainly be viewed as only an interim solution.

On this same question of permitting substitution of dilution for treatment, it is useful to observe, however, that project planning should be based on the concept of optimum utilization of dam sites and that, for this purpose, all possible uses for the waters which could be stored in a proposed reservoir site should be investigated. If, under these circumstances, economic studies should indicate a need for dilution water at a future date, a pollution source could now use this dilution to permit a lower degree of satisfactory treatment. Such substitution should be limited, however, to the period of time during which the water is not needed for higher priority uses. Present use of stored water for dilution should not grant a right in perpetuity. Also, it would appear proper under these conditions to require the pollutor to pay an appropriate amount for the dilution water as a substitute for the costs of the postponed treatment plant. In the present discussion, we are dealing primarily with those situations where a general pollution problem exists in spite of the provision of required waste treatment, and where dilution water as an additional pollution abatement measure for general public benefit, is provided at Federal expense.

Proposed Policy Regarding Use of Low Flow Augmentation for Pollution Abatement. On the basis of the foregoing discussion, it is proposed that reimbursement for pollution abatement benefits resulting from low flow augmentation from Federal reservoirs be based on the following policy:

1. Incidental pollution abatement benefits resulting from the operation of Federal projects for other purposes may be credited on a non-reimbursable basis to those projects even though construction of treatment facilities which would otherwise be required is thereby postponed, but such benefits should be computed for a limited time only, based upon a projection of total future demands upon the stream for water for all purposes.
2. Where pollution abatement by means of low flow augmentation is proposed as a non-reimbursable planned purpose of a Federal project, only those pollution abatement benefits should be credited to the project which would be produced

after the pollutors have first provided efficient secondary treatment of their wastes, or if this is not possible because of the type of wastes, then treatment to the degree economically permitted by existing knowledge; provided however, that where secondary treatment or its equivalent will ultimately be provided but will require time to introduce, a specific phasing in period of time may be allowed during which credit for non-reimbursable benefits below secondary treatment levels may be claimed for the project.

3. In those situations where the degree of reduction of BOD or other pollution to be achieved by treatment, or the minimum oxygen level or concentration of pollutants to be permitted in the stream, as established by the State, is below the level which efficient secondary or equivalent treatment can provide, only those non-reimbursable benefits should be claimed for dilution water from Federal reservoirs which would be produced following efficient secondary treatment or its equivalent.

4. In those situations where different criteria for permissible pollution are set by different States on the same interstate stream, the higher of these criteria should be used as the datum above which non-reimbursable benefits for low flow augmentation should be computed, because otherwise the pollutors in the State with the lowest criteria would receive an unmerited benefit at the expense of the pollutors in the State with the higher standard. In no case, however, should

the non-reimbursable benefits claimed be based on less than efficient secondary treatment or its equivalent.

Section II

Procedures for Evaluating Water Supply and Pollution Abatement Benefits.

Difficulties in measuring benefits. The measurement of water supply and pollution abatement benefits derived from water stored in Federal reservoirs is rendered difficult by the varied nature of these benefits and by the absence of adequate economic tools for the purposes.

Municipal and industrial water supplies serve a wide variety of domestic and public purposes, including transportation of domestic and industrial wastes. The water provided enters into, but is only one of many ingredients in a great number of industrial and other processes. It promotes or preserves health, provides recreational, esthetic and other satisfactions of quite an extensive, but often quite an intangible nature, and otherwise plays a basic role in our whole life process.

It is generally agreed that the price paid for a water supply does not necessarily represent the value of the benefits derived from its use. Yet the true value of these benefits is difficult, if not impossible, to determine, because social as well as economic values are involved*, and no generally acceptable method of measuring them has yet been devised. Thus, arbitrary and admittedly inadequate methods must be relied upon for their determination. This condition is typical of all situations where the benefits involved are of a more or less intangible nature.

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* See addendum No. 1 on "An Approach to the Problem of Determining the Value of Water"

The abatement of pollution in a river by the release of stored water during low flow periods prevents damage to the river by improving its quality as well as increasing its flow, thereby permitting it to perform more satisfactorily a number of functions which it could not otherwise do. Thus, the physical and esthetic appearance of the stream and its environment can be preserved or improved, fish and aquatic life supported, recreation enhanced, tastes and odors reduced, and dangers to health and damages to physical property greatly diminished. Excess costs of treating polluted waters for water supply purposes may also be prevented. Heat pollution may be dissipated by the lowering of river temperatures. In some cases, the benefits may, of course, be negative in character, that is, they may be detrimental to the river as in the case of oxygen deficient water released from the bottom levels of a reservoir.

Incidental benefits of a similar nature may also result from releases of water for other purposes such as municipal or industrial water supply (where the stream is used as the transporting vehicle), navigation, flood control, or power generation.

Some of these various benefits from low flow augmentation can be evaluated directly. For example, it is possible to determine the reduction in costs of treating withdrawn waters before use, as well as any reduction in the cost of treating wastes discharged to the river, made possible by the dilution. Potential pollution damages to river structures, boat hulls, engines, etc., can be computed. It may even be possible to evaluate the adverse effects of polluted waters upon the market value of abutting properties. But many of the damaging effects of pollution which are reduced or eliminated by dilution are difficult, if not impossible, to evaluate in monetary terms by existing methods. This is particularly true of damages to fishing, recreational pursuits, esthetic values, and environmental influences in general, where benefits can be described in terms of numbers of persons served or other similar quantities, but cannot be reduced to dollars.

For those situations where dilution results in the elimination of the usual treatment facilities which would otherwise be required, the upper limit of the value of the benefits produced by the dilution would normally be the costs of the treatment plant eliminated. In those situations where dilution would still have been required, even if the treatment plant had been built, benefits in addition to those represented by the cost of the treatment plant eliminated must also be evaluated. These "excess" benefits would be computed in the same manner as those discussed below, where all possible treatment has been provided, but where dilution is still required to abate the pollution in the stream.

Presently accepted method of assigning values to water supply and pollution abatement benefits. As indicated above, no satisfactory method has yet been devised for evaluating some of the described water supply and pollution abatement benefits provided by stored water, although many people feel that they far exceed the cost of acquiring the necessary water. In the absence of an acceptable technique for measuring them, these benefits have, for convenience, arbitrarily been equated equal to the cost of the cheapest feasible alternative means of achieving the same benefits, in the absence of the proposed project. Where a feasible alternative is cheaper than the project under study, it would, of course, normally be expected to be adopted in lieu of the project, or would in any case be considered the upper limit of the cost which the beneficiaries would be justified in paying for the project in question, as well as the arbitrary measure of the benefits to be derived from it. Thus, even if it were not necessary to assign a value to the benefits from a proposed Federal water storage project, it would still be necessary to explore all possible alternatives in order to determine whether the project is economically justified, and the arbitrary adoption, for mere convenience of handling, of some one alternative, to the exclusion of all others, is improper, unless it can be shown to be in fact the most economical practicable alternative available.

This arbitrary procedure for evaluating water supply and pollution abatement benefits is admittedly unsatisfactory and provides values which leave the investigator with the frustrating feeling that they may be very wide of the mark. In fact, it really does not solve the problem at all since it begs the question by flatly assuming that the benefits warrant the proposed expenditure in the first place. This position is justified, of course, in those reimbursable situations where the beneficiaries are required to pay the costs or are willing to contract for their payment, but offers no solution to the problem where the costs are non-reimbursable. Until such time as economists can provide a more workable technique, however, we are pretty much stuck with this concept as the basis for the evaluation of these benefits.

Alternatives to be studied in evaluating a water storage project. In the previous paragraphs, it was pointed out that both the limit on justifiable expenditure for, and the value of the benefits from a water storage project were, in the absence of any better procedure, taken to be equal to the cost of the cheapest feasible alternative method of achieving the same benefits in the absence of the project. Application of this concept makes it necessary to determine the alternative to be selected in each case, as the basis for measurement. The only limitation on the consideration of alternatives is that they must be true alternatives, which could in fact be built, and not hypothetical concepts conceived merely for purposes of computation.

With respect to a municipal and industrial water supply project, the most obvious alternative is another water supply source. This may be a single purpose reservoir, either on some other stream, or at the site of the proposed project in its absence. It may also be ground water. However, in some instances, other alternatives are available, such as re-cycling or other conservation of the existing supply to extend its utility, or in the case of water for cooling, resort to cooling ponds to air cooling. All such alternatives should be explored and evaluated. In approaching this problem, cognizance should also be taken of the need for additional storage to provide additional water to dilute the wastes produced when a water supply is used.

Several types of alternatives are also available for measuring benefits from low flow augmentation. As explained above, in those situations where dilution makes it possible to avoid construction of a primary or secondary treatment plant, the cost of such a plant is the most obvious alternative. Above the secondary treatment plant level, other alternatives include (1) a single purpose storage reservoir, either on the site of the proposed multiple purpose project in its absence, or elsewhere, whichever is cheapest; (2) tertiary treatment facilities, such as a super-treatment plant or a lagoon, which would achieve a reduction in the pollution load on the stream equal to that which would be accomplished by the proposed dilution; (3) other methods of dealing with the wastes in the first place in such manner as to prevent them from reaching the stream, or (4) other methods of providing the benefits which are produced by low flow augmentation.

With respect to a possible super-treatment plant as an alternative, benefits must, of course, be computed on the basis of the entire cost of the plant, not on its rental value during the limited periods when treatment in excess of standard secondary treatment would be required, since there would be no other use for such a theoretical plant, and it would, of necessity, stand idle during those periods when dilution was not required.* The costs of such a plant would therefore include total capital outlays, interest and maintenance costs, plus those operating costs incurred during actual periods of operation.

Closely akin to the super-treatment plant alternative is that of a tertiary stabilization lagoon or "polishing" pond. This method may perhaps be much cheaper than the super-treatment plant, but there are serious drawbacks to be considered. These ponds require considerable space. Since most cities are located in or near a river bottom, there might not be room either for such a pond, or for the hydraulic head required for proper functioning without expensive pumping. In some locations the large areas of land required would also be costly. Furthermore, the delay caused by these lagoons in returning flows to the stream at times when needed downstream might also be considered as a damage since this waste water has value under these conditions.

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* See addendum No. 2 for additional discussion.

A variant on the treatment lagoon concept is a simple storage lagoon, which would merely impound the treated waste water effluents until such time as the flood flows of the river are great enough to dilute these wastes without damage to the stream. Such storage lagoons would require less storage volume than the water required to dilute them, and could also be much deeper and of much less surface area than treatment lagoons, thus reducing evaporation. However, suitable sites would probably be difficult to find in river bottom areas. In addition to the drawbacks of space needs and hydraulic head mentioned above, this scheme also has the disadvantage of deliberately withholding water (even though polluted) from the stream at a time when its low dry weather flow might require that the additional water be made available.

In those situations where the purpose of dilution is to make possible the withdrawal of water further downstream for water supply purposes, the cost of an alternative source of water for these downstream supplies could serve as the basis for measuring the benefits from low flow augmentation, and should be explored. In fact, if the alternative source of water supply is cheaper, it should be adopted, since dilution would then be uneconomical in the first place.

For those situations where a natural pollutant such as a chloride or sulphate may be too concentrated to permit use of the water for municipal and industrial purposes, but may not be detrimental to fish or recreation, dilution would appear to be uneconomical unless a demand either existed or was anticipated within the period of analysis, for such a water supply from the river. Also, it might be possible to divert such natural pollutants from the area of use, as an alternative.

With respect to recreational and similar benefits from a stream, which would be produced through dilution, the cost of providing similar benefits by alternate means should be explored. In many such situations there probably would be no apparent alternative facility, but, a search in this direction for value measurements would seem to hold out possibilities as compared with the task of tackling recreational values directly.

In most cases above the secondary treatment level, perhaps the most practicable alternative for measuring the value of benefits from the project will be the alternative single-purpose storage reservoir which would be able to provide the same water supply water as that provided by the project under study. All possible sites for such a reservoir should be investigated, including a reservoir on the project site in the absence of the project.

In computing the size and cost of the various alternatives, it will, of course, be necessary to undertake a careful operational study of the stream in question, based on hydrologic records, to determine the frequency, duration, and actual volumes of flows of the river during its low flow stages. These data, coupled with the patterns of timing and concentration of waste water discharged to be expected, and the relative costs of correcting the situation under various assumptions regarding permissible stream damage, are used tc indicate the volumes and durations of dilution water releases to be provided. Such a study will provide the basis for determining the total annual amount of dilution water to be released, and therefore the storage space to be provided, or, in the case of super-treatment, the maximum treatment plant capacity to be provided. If a storage lagoon is envisioned, the frequency, magnitude, and duration of the flood flows during which the lagoon would be discharged, must also be determined by a hydrologic study in order to determine the maximum waste storage volume required.

In making a comparison between the cost of the Federal project and that of an alternative, the procedure is usually complicated by the fact that most alternatives would usually be financed by non-Federal agencies over a shorter period of time, and at a different interest rate than the Federal project, Because of this fact, it is necessary to convert both costs to a common base for comparison. This is perhaps most easily done by reducing all costs to present worth. Thus, the total of both interest costs and of operation, maintenance and replacement costs for both the Federal project and the alternative would be reduced to present worth and added to the initial investment costs, to get a total figure in each case for comparison. It is also possible to make the comparison on an average annual cost basis by converting all figures to a common time period.

Addendum No. 1

The Problem of the Value of Water

A basic problem in determining the value of water stems from the concept that water is endowed with some fundamental intrinsic value which is inherent in its nature. This assumption is obviously fallacious. Water has many values, depending on location, condition and volume of supply and intended use. In any given location, water, regardless of the benefits and satisfactions it conveys to the user, is worth what it costs to get it, up to the point where cost exceeds the price purchasers (used here in the broadest social as well as commercial sense) are willing to pay. In the latter situation, price voluntarily paid represents the limit of its value, this limit often being dictated by nothing more than sheer judgment on the part of the purchaser.

The cost of acquiring a water supply for a particular use includes both direct costs and indirect or associated costs. These indirect costs include such things as benefits from other possible uses for the same water, which must be forgone or renounced, or detrimental affects on other following uses and users of the same water, for which compensatory measures must be provided. It is often difficult to measure these indirect costs. In many instances they represent social costs which are not reflected in the costs assigned to the water project. Some of these affects and interrelationships are discussed in following paragraphs.

A further difficulty in determining water value arises from a tendency to confuse costs with reimbursements, or with accounting items used in tax and rate making procedures. Costs represent expenditures (or benefits forgone), which must be made in order to acquire water. Reimbursements involve the question of who pays these costs--not necessarily the same people as the users. Accounting quantities used for tax or rate making purposes sometimes involve concepts other than or in addition to actual costs. These distinctions must be kept clearly in mind, since the determination of "who pays what" involves social and political as well as economic considerations.

Water serves many purposes--some of which are absolute in the sense that there are no alternatives to such uses. The most important of these is, of course, for domestic water supply--household use. In the most limited and narrow sense this means direct human and animal consumption of water. Other household uses such as for cooking and personal and household cleansing are second, followed by transportation of wastes, watering of gardens and lawns, washing of cars, etc., in some descending order of importance. For the first of these uses, water is worth whatever it costs to acquire, since life itself is at stake. Under these circumstances, the limit on value is equal to the total resources available to the people for the acquisition of water, since the only other choices are to move on to some more favorable location or to perish.

For all other uses, there usually are choices and alternatives which help to establish value, although these choices are not necessarily easy to make. Most domestic uses have to do with the quality of human living and environment, and benefits relate mainly to matters of human health or welfare. Cleanliness, sanitation, fire protection, and maintenance of gardens, lawns and parks all contribute not only to physical health and well-being, but to mental health, and to esthetic, social and cultural betterment, both on an individual and a community-wide basis. Such benefits are not as susceptible of monetary measurements as are benefits from uses of water for other more material(or commercial) purposes. Thus, where water is relatively plentiful, the value of water to be used for health and welfare purposes is largely a matter of the judgment or choice of the purchasers* with respect to the expenditures required to acquire the water, when compared with other types of benefits which might be secured from expenditure of the same funds for other purposes. In areas of inadequate economic resources or of low income, this choice, even where water is plentiful, will, however, be dictated largely by the demands upon scarce funds for more fundamental needs such as food, clothing and basic shelter.

On a community-wide basis, the choice is frequently affected by the attitude of citizens toward taxes or other public charges. Communities are often quoted as being unable to afford an addition to their water supply system, or a sewage treatment plant to clean up water after use. What these communities are really saying is that their citizens prefer to spend the additional sums involved for more chewing gum, gasoline, movies, or televisions, rather than for the extra taxes or service charges required to pay the costs of water for green lawns, clean streets, fire protection or more fishing in the river. This attitude arises largely because these water facilities or services are frequently not paid for directly by the citizen, and the relationship between the benefits and the payments is therefore tenuous, or the values to be derived from the extra water or the cleaner river are not directly comparable to chewing gum or a TV.

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* The term "purchaser" is used in the broadest sense and is not intended to be synonymous with the ultimate consumer. For public health, welfare and other public policy reasons, the purchaser can be and often is a public body which does not necessarily receive adequate compensation from the ultimate consumer, but elects to subsidize his use of water as a general public welfare policy. Here, again, the confusion which arises between costs and reimbursements must be kept clearly in mind.

The value of the water is nevertheless still based on a choice, dictated by the cultural pattern or the standard of living of the people of the community.

In arid areas, such choices tend to diminish or disappear, and the philosophy behind water use changes character, since a limited water supply would naturally be applied first to agriculture or other material productive effort, rather than to, say, watering lawns, a deferrable use in the face of more basic economic need.

With respect to most public uses of water, such as for recreational facilities, sport fish propagation, or the transportation of wastes, no precise monetary evaluation of benefits can usually be developed for comparison with costs or with benefits from other types of usages which can be so evaluated. A non-monetary, but nevertheless definite quantitative evaluation can often be made, however, Numbers of people served per year, or numbers or pounds of fish raised or caught per year provide a guide. The choice is still largely one of judgment in the final analysis, however, because specific monetary benefits from possible alternative industrial or consumptive uses must be compared, from a broad public point of view, with the non-monetary general benefits from these public uses. (Even so, some of these latter uses can be shown to induce substantial secondary activities, which are measurable in money, such as stimulation of local employment, manufacture and sale of equipment, sale of food, gasoline, and other services, which might provide a basis for comparison with similar specific local benefits from commercial uses.)

Still another category of uses, which lie in a half world of susceptibility to comparative evaluation, is concerned with such uses as industrial or power plant cooling or generation of hydroelectric power, where the basic costs of development for such uses are comparatively low per unit of water involved. In these instances, the water is usually passed on to others for such other uses as municipal or industrial water supply, recreation, fish propagation or sewage effluent dilution, but is modified either in temperature, or time of availability, to such a degree as to materially reduce its suitability for these other uses. These detrimental effects, which are often not susceptible to monetary evaluation, must nevertheless be taken into account along with the direct monetary costs of developing the water supply for these commercial uses. Where the succeeding downstream uses are sufficiently important, public authorities may be faced with the necessity of determining whether the initial commercial uses shall be denied or additional costs imposed upon the commercial users for plant modification in order to reduce the detriments to these other downstream users. (Use of cooling towers, recycling and re-regulating reservoirs are examples of such plant modification.) With the imposition of these additional costs, the cost of the water may exceed the value to the prospective commercial users, who may then abandon their proposals to utilize it for cooling or power generation, or may adopt alternative methods of achieving their ends.

It is only when one gets away from the intangible field of domestic and community or other public uses involving problems of health and general public welfare, that it becomes possible to apply what may be called market values to water. There are choices, of course, but under these circumstances it can be assumed that the choice would normally be based on the greatest economic return. For example, it is entirely possible, in many instances, to determine on a comparative economic basis the production and employment returns from, say, irrigation versus navigation or industrial water use. Development of a water supply for an irrigation project of low yield might prove uneconomical, but might be justified for a recreational or an industrial development which provides sufficiently high returns to warrant the expenditure.

Within the area of industrial use, evaluation of a water supply in relation to cost would again depend on the alternative returns from various types of industries, some industries being unable to meet high costs, others being entirely able and willing to do so. Even in this situation, choice varies with location, since an industry may be unwilling or unable to meet high costs in one location, as in Eastern steel mills, but may, because of a more favorable location with respect to markets, be prepared to pay higher costs either directly for the water, or for measures to conserve it--as in the case of the Fontana steel mill in California. Even this situation is not static. Eastern steel mills are unwilling to pay high costs for water only because of the existing plentiful supply. At some future time, other demands for water in these areas may make it so valuable that these mills would elect to install conservation measures rather than pay higher charges for the water.

As the competition for water increases with increasing population and the multiplication of uses, the cost of acquiring or providing water of suitable quality will gradually increase for various reasons. Correspondingly, the value of water will also increase, both because of increased costs and because of competition for scarce supplies. Thus, there may arrive a time when, for example, the cost to the public for the use of rivers as residual waste carriers (even after so-called "complete" treatment) in terms of detriments to other uses and users, such as water supply, recreation or fish culture, may be so great as to warrant a search for other methods of waste handling, or for more elaborate (even though more expensive) waste treatment facilities such as desalination of secondary treatment plant effluent.

The foregoing discussion and examples attempt to point out that each water use and development situation must be evaluated on its own particular merits and to demonstrate that no basic general value can be assigned to water per se, either with respect to place or time of occurrence or use. This does not mean that efforts should not be made to determine the value of water for any given use or circumstances. Such determinations are badly needed. But, even in specific situations, the determination of the economic and social value of water is difficult, and much work is required to develop suitable techniques and procedures for making such evaluations.

Addendum No. II

Computation of Alternative Treatment Plant Costs as a Basis for Evaluating Pollution Abatement Benefits from Low Flow Augmentation

Suggestions have been made that the waste treatment cost figures developed for the use of the Senate Select Committee, as shown in Committee Prints 9 and 29, be used as the basis for computing the costs of treatment as an alternative to dilution. These figures are inadequate for this purpose. They were developed to indicate the total cost of providing normal standard treatment on a continuous basis in a river basin. Beyond this, Committee Print 29 had as its objective the determination of the volume of stream flow required to assimilate such treated wastes, on a basin wide basis, but did not attempt to evaluate the benefits which would result from such dilution. The Committee's problem and the one we are dealing with in attempting to place a benefit value on water provided for low flow augmentation are two separate stages in the over-all problem of the management of water quality in a river.

The cost of treatment which would be required to achieve the same results as dilution after secondary treatment are far higher than the costs of standard secondary treatment, and are further complicated by the fact that such super treatment would only be required at spasmodic intervals when normal river flow falls below the point where the stream could assimilate the treated effluents. Thus, the super-treatment plant must be visualized as a standby plant constructed solely for this purpose, and standing idle during those times when the river flows were high enough to render use of the plant unnecessary. Under these circumstances, the cost of removing a unit of BOD by the super-treatment plant must be computed by charging out the entire capital cost of the standby plant against this spasmodic service and would thus be far higher than that derived from the figures contained in the Committee print.

SHOULD THE PUBLIC HEALTH SERVICE TAKE A STAND AND MAKE SECONDARY TREATMENT MANDATORY?

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Let's take a stroll down the streets of Edinburgh in jolly old England about a century ago. The cobblestone streets, the quaint dress of the passers-by, the building architecture, and the store fronts with manuscript signs soon give us the "plum-pudding" atmosphere of a Dickens' novel. Suddenly, the folks around us look panicky and head for cover. for the words "GARDY-LOO!" have been sounded by a housemaid's voice above us. Just as the word "FORE" means take cover on the golf course, the words "gardy-loo" were the maid's warning that she was throwing the contents of the night soil pot out of the window. Having hesitated too long to take cover, we are quite happy to return to the present day, where the words "gardy-loo" no longer rend the air with shattering impact.

Modern sewerage systems have made the words "gardy-loo" obsolete; by connecting each household, hotel, hospital, and industry with a sewer, the noxious, bacteria-laden, and potentially poisonous wastes of a community are no longer a sidewalk hazard. Instead, they flow swiftly and silently to the nearest watercourse -- where, without even the courtesy of the warning words "gardy-loo" they are often thrown into the water plant intake of a downstream community. More than warning words are needed, however; the sewage must be treated and purified -- but by whom? -- the city where the wastes originated? -- the receiving stream? -- or by the downstream water plant operator? Only the factor of economics prevents unanimous agreement that purification should take place at the point of origin.

The word "only" was used not in the sense of minimizing the importance of economics but to signify that it is the one reason that prevents 100 per cent purification of waste water by all water users. There is a price tag on every gallon of waste water, from the time it is flushed from the user's premises until it is used again, or reaches the sea. Sewers and interceptors are not free; treatment costs increase with each per cent removal of waste-water ingredient; degradation of the stream costs a segment of society their health, recreation, and welfare; and it costs the downstream user not only the price of an elaborate water treatment plant with alert operators and high dosages of chlorine but a sword of Damocles that hangs constantly over their heads in the form of a threat of virus, untreatable toxic materials, and the potential malfunction of the human or mechanical operation of their water-treatment plant.

Until 1948, the Public Health Service had done little more than sound the "gardy-loo" warning for the stream polluters. It had recognized and sanctioned dilution as a money-saving substitute for waste treatment as long as there was sufficient water in the stream to "assimilate" the wastes. Except for PWA-WPA projects, Federal financial assistance was offered for neither waste nor water treatment; individual treatment plants were the responsibility of the water users and their respective state health departments. It is interesting to note that today the Public Health Service has taken a stand and is granting financial assistance for the construction of sewage treatment plants but not for dilution water nor water treatment plants. Let's go back to the year 1948 and see how this came about.

In that year, the Senate Committee on Public Works (Report No. 462, 80th Congress) summarized the national problem:

> "Water pollution has become a matter of grave concern in many areas, and its damaging effects on the public health and natural resources are a matter of definite Federal concern as a menace to national welfare. Abatement must be undertaken to control it."

The committee report then stated the Federal responsibility in solving the problem: "The Federal Government should take the initiative in developing comprehensive plans for the solution of water pollution problems in cooperation with the states."

As a result of the committee's findings, the Taft-Barkley bill, Public Law 845, was passed by the 80th Congress. This bill was the Nation's first Water Pollution Control Act and put the Public Health Service in the business of water pollution control by specifying the responsibilities of the Surgeon General:

> "The Surgeon General shall, after careful investigation, and in cooperation with other Federal agencies, with State water pollution agencies and interstate agencies, and with municipalities and industries involved, prepare or adopt comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground waters. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural, industrial, and other legitimate uses ...."

The bill also instructed the Surgeon General to encourage interstate compacts for the prevention and abatement of pollution, to support and aid technical research to devise and perfect methods of treatment, and to provide technical services to state and interstate agencies and to municipalities in the formulation and execution of their stream pollution abatement programs. Financial aid by loans to local agencies for the construction of pollution abatement works was authorized, but none was appropriated under the original Act. Enforcement of water pollution control measures was authorized, but only after state efforts had failed and with consent of the upstream state from which the pollution was originating. The Senate Committee on Public Works made a prophetic statement with regard to this bill:

> "... failure to accomplish adequate progress in pollution abatement under the terms of this bill, through cooperative efforts of the Federal and State agencies, will undoubtedly call for much stronger and more direct Federal enforcement measures at some subsequent session of the Congress."

The horrendous job of organizing, implementing, and carrying this new comprehensive program into the states was shouldered by Carl E. Schwob, Chief of the then embryo Division of Water Pollution Control. Under his masterful and dynamic leadership, the entire United States was divided into ten major drainage areas, with a field office staffed by four to seven engineers and scientists in each basin.

Before summarizing some of the accomplishments that were realized during the first three years of the Division's existence, it should be noted that no attempt was made to take a stand on any specific degree of waste treatment, but instead, every effort was expended toward achieving a feeling of cooperation between the states, industries, conservation groups, and other Federal agencies. This period was an all-out attempt to sell the Golden Rule to the Nation's water users.

The following are excerpts from Mr. Schwob's statement to the Committee on Public Works of the House of Representatives, 82nd Congress, on May 20, 1952:

> "... I like to think of our multiple functions in three broad categories .... First, comprehensive program planning and development activities; second, execution of the comprehensive program; and third, technical services and research which support all other activities.

> "Under the first category, ... we have issued reports covering the 226 basins in the United States, of which 146 are interstate .... These statements represent joint statements of the Public Health Service and the States involved ... (and are) ... comprehensive blueprints of pollution abatement needs. We have developed ... a model State Water Pollution Control Act which was recommended by the council of State Governments for favorable consideration. ... we are participating in the Arkansas-White-Red and the New England-New York Inter-Agency Committees.
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> "Under the second category, execution of the comprehensive program ... we have ... worked directly with State agencies to bring about solutions to interstate pollution problems ... encouraged the formation of regional pollution-control councils ... (at least one of which has) ... adopted (for its area) uniform water quality objectives and treatment works design standards ... stimulated pollution control activities within the States by making federal funds available for studies, surveys and research.
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> "Under the third category, "Technical Services and Research," we have ... set up a National Technical Task Committee to work directly with industry ... and placed under construction the Environmental Health Center at Cincinnati which is about 60 per cent completed ...."

This program, which was successfully revealing and defining the Nation's water pollution problems was nearly scuttled within a year after the above report, by a temporary but devastating slash in Federal funds -- Mr. Schwob's health failed, the basin offices were disbanded, and many of the highly skilled personnel transferred to other areas of activity. Could it be that the Public Health Service was approaching a point where it would have to take a stand in enforcing pollution abatement measures that would be costly for members of certain pressure groups? Perhaps we should have heeded the words of Plutarch (Lives--Crassus, p. 651) "Economy, which in things inanimate is but money making, when exercised over men becomes policy." Is the public ready for us to take a stand at this time? The cost of secondary treatment is even higher today than it was eight years ago; but then the public is more aware of the need for more clean water today -- or is it?

Having made my point regarding the chaos that occurred during the spring of 1953, I must now qualify it by stating that Congress did extend the original act just prior to its expiration date in 1953 but after the basin office organization had been dismantled. Mr. A. F. Weiters succeeded Mr. Schwob during the reorganization period, and the program has surged forward since 1955 under the forthright leadership of Mr. Gordon McCallum. A second Federal Water Pollution Act, Public Law 660, was enacted by the 84th Congress in June, 1956. Since this Act is the foundation of our present Division of Water Supply and Pollution Control, we might well review its provisions to see if it will permit us to take a stand on secondary treatment.

The second Act is very similar to the first, with two significant changes: (1) authorization of Federal financial assistance in the form of grants (instead of loans) to municipalities for the planning and construction of needed sewage-treatment plants; and (2) a more workable provision for Federal enforcement where needed to clean up interstate pollution.

Our present program encompasses seven general areas pertinent to pollution:

1. Basic Data

   This program includes: (a) a national network of seventy-five stations on interstate streams to measure water quality; (b) inventories of water, sewage, and industrial waste facilities in the United States; (c) compilation of data on contract awards for water facilities, sewerage, and sewage treatment facilities to show what progress is being made in meeting the nation's needs, and; (d) economic studies to find ways of determining what pollution is costing the American people and the costs of controlling it.

2. Program Grants

   The Act authorized $3 million a year in annual Federal grants to support state and interstate pollution control programs; these agencies have used the grants, supplemented by two or three times the amount of the grant with local funds, for employing technical personnel, for purchasing special laboratory and field study equipment, for research, and for other purposes in administering state laws.

3. Construction Grants

This program has been very successful in stimulating the construction of sewage treatment facilities, with authorization of $50 million annually. These have been made primarily to cities of 125,000 population or less, and local funds have been applied in a rate of about 6:1.

4. Research

Aimed principally at pollution abatement, our research is carried on mainly at the Robert A. Taft Sanitary Engineering Center. Some of the projects under way include finding a cheaper and more efficient sewage treatment process and methods for freeing water supplies from viruses, detergents, insecticides, radioactive substances, and other substances which can make a water supply unsafe. The Act also provides for research grants to public and private research agencies, as well as qualified individuals.

5. Interstate Enforcement

Where pollution of interstate waters endangers the health or welfare of persons in a state other than the one in which the pollution originates, the

Public Health Service is empowered to take action to abate such pollution. Such action includes first, a conference with the state and interstate agencies involved; second, a public hearing before a board appointed by the Secretary; and finally, Federal court action.

6. Training

The Sanitary Engineering Center gives short, intensive laboratory and classroom courses and holds seminars and conferences on new subjects of interest for the benefit of engineers, chemists, and other scientists from Federal and state agencies, municipalities, industries, and foreign countries.

7. Technical Assistance

States which have requested technical assistance from the Division have received services such as full scale river surveys, evaluation of state laboratory operations, evaluation of new waste treatment processes, and special investigations into water-borne disease epidemics, and fish kills. Close liason with the major industries

> of the Nation is maintained by the National Technical Task Committee on Industrial Wastes. It has two basic purposes: to serve as an advisory capacity to the Public Health Service, and second, to serve as a forum whereby the industrial representatives may exchange information on their common waste disposal problems and make regular reports to their sponsoring groups.

We have traced the course of the Public Health Service's water pollution control program from its birth, through its turbulent growing pains and finally its present mature, multiple-phase development. Our main purpose has been to reveal the complexity of the Nation's water pollution problem and the folly of any attempt to have taken a hard stand on universal secondary treatment up to the present time. Would it be wise to take such a stand now? Would it ever be?

Perhaps population density might be a criterion for determining when we should insist on universal effluent standards. Klein* compares England's use of effluent standards with the United States' program: "In the U.S.A., stream standards rather than effluent standards are preferred for legal purposes and this is understandable in a country where, in general, rivers are large and pollutions occur at wide intervals." A comparison of the average population density of the two countries bears him out, since that of England is 81 persons per square mile and the United States is somewhat less, 50.4. However, upon taking a closer look, we find that eighteen of our states have a greater population density than England. New Jersey and Rhode Island, the most densely populated, have an average of about 800 persons per square mile. At least four of the eighteen states now have some form of effluent standards. Incidentally, England has not strictly adhered to effluent standards, for Section 5 of the 1951 Rivers Act left open whether effluent standards, stream standards, or both should be prescribed.

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*Klein, Louis, Aspects of River Pollution, p. 541, (1957).

Regardless of where we might draw the line for a minimum degree of treatment, we must expect sharp criticism for being unreasonable. For example, in implementing the Construction Grant program, the Public Health Service established rules and regulations that require treatment to remove, substantially, 100 per cent of settleable solids (primary treatment) as a minimum to be elegible for a grant-in-aid. Thomas R. Camp* has cited several instances where the receiving stream had sufficient flow to assimilate the wastes, and he used these examples to substantiate his following statement:

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*Camp, Thomas R., ASCE Sanitary Engineering Div. Journal, Vol. 87, SA1, January, 1961.

> "These (minimum requirements) tend to have the force of law compelling primary settling whether it is needed or appropriate to accomplish the required result in the receiving waters, and to divert attention from the much more important reason for sewage treatment, which is the destruction of pathogenic bacteria and viruses."

He has made a strong plea for chlorination only, where the dilution ratio is sufficient to handle the organic load in sewage: " ... post-chlorination of well settled sewage produces no better bacterial results in the receiving waters than does chlorination of comminuted raw sewage." We do not choose to argue the point, especially since we agree so heartily with his statement regarding the importance of destroying pathogenic bacteria and viruses; however, the following points are here listed as a token rebuttal to his criticism of our stand in the Construction Grants program: (1) The Public Health Service, by virtue of its role in carrying out Public Law 660, must give due regard to not only waters for public water supplies, but also the propagation of fish and aquatic life, recreational purposes, and agricultural, industrial, and other legitimate uses. (2) His comparison of the efficacy of chlorine on raw sewage and primary effluent involved the use of a laboratory blendor to simulate a comminutor in breaking up the bacteria-laden clumps in raw sewage for more effective contact with the chlorine; a comminutor is not intended to, nor does it approach, the homogonizing action of a laboratory blendor. In actual practice, the center of these clumps might be expected to pass into the receiving stream without being contacted by the chlorine. (3) Laboratory beakers should not be considered as an adequate device for simulating the receiving stream; after-growth of chlorinated sewage bacteria may be expected to occur according to the turbulance, nutrient, and other characteristics of the particular receiving stream. (4) Malfunction or interruption of the chlorination would result in the raw sewage being discharged directly to the stream.

In the light of our experience in administering the Water Pollution Control Act in this country since 1948, the experience of England in applying effluent standards, and the sincere objections of qualified men like Mr. Camp, it appears inadvisable for the Public Health Service to take a stand and make secondary treatment mandatory. Instead, we should continue to encourage the states to classify their streams and thus reveal the degree of waste treatment needed to maintain the desired quality; to stimulate more intrastate pollution control activities by increasing the funds available for Program Grants; to stimulate a faster rate of construction of pollution-abatement structures (with a degree of treatment specified on a case-by-case basis in accordance with the receiving stream's use-classification) by increasing the funds available for Construction

Grants; to increase the latitude and intensity of research on sewage and waste treatment that has the goal of producing an effluent that not only does not require dilution water but is free of toxic and pathogenic materials, at a reasonable cost; and finally, to continue all other phases of our current program with ever increasing enthusiasm and zeal.

By supporting the state programs for pollution abatement and control in their intrastate streams, the Public Health Service will need only to take a stand on the quality requirements of waters passing from one state to another with conflicting quality requirements. No across-the-board stand should be specified in advance, for each case must be decided on the quality requirements of the downstream state users. Conventional primary, secondary, and even tertiary or polishing treatment are primarily limited to removal of oxygen-demanding organic materials.

Pre and post-chlorination may become mandatory to prevent viral epidemics if the rising trend in those diseases is proved to be water-borne. In the year ending September 3, 1960, nearly 34,000 cases of infectious hepatitis were reported in the United States -- a 62 per cent increase over the preceding year. Also, the current Public Health Service program of nationwide surveillance of fish kills has revealed that 73 out of 185 cases were caused by agricultural poison and 57 of the 185 by industrial wastes. Surely something more drastic than conventional secondary treatment is indicated here. As a preventive health measure, it may be necessary to prohibit the discharge or land-use of any potentially toxic chemical to a stream until its degree of toxicity has been established.

In agressively attacking the Nation's water pollution problems, we are assured of uninterrupted support (as contrasted with the spring of 1953) by the recent statement of President Kennedy in his address to Congress on February 23, 1961: " ... I urge that this legislation strengthen enforcement procedures to abate serious pollution situations of national significance." Also by the legislature: Representative Blatnik, Chairman of the Rivers and Harbors Subcommittee of the House Committee on Public Works, has introduced H. R. 4036 to the 87th Congress to strengthen the Water Pollution Control Act. His bill would increase Construction Grants authorization to stimulate the construction of more sewage treatment plants and would increase the monetary limit for individual cities from $300,000 to $600,000; Federal enforcement would be extended to all navigable waters instead of the present interstate waters; it would establish a $25 million Enforcement Construction Grants Fund to be available for financially hard-pressed communities required to construct treatment facilities as a result of Federal enforcement action, such funds to be available over and above regular state allottments of construction grants. The bill also retains the states' primary rights and responsibilities for control of water pollution and increases Federal grants to state and interstate agencies for administration of their programs from $3 million annual authorization to $5 million. The stimulus of these Program Grants on state pollution control activities cannot be overestimated. To cite one of the many states which is making great strides in controlling pollution, California (which received $133,700 of Program Grant funds in 1960) has its Dickey Water Pollution Control Act. By vesting primary responsibility in nine regional water pollution control boards, with statewide policy formulation by the Water Pollution Control Board, it can take pride in an impressive eight-year record of progress in pollution control even while its population increased by 33 per cent.

Bills identical to Mr. Blatnik's were also introduced by Representatives Frank E. Smith of Mississippi, John D. Dingell of Michigan, and Senator Hubert H. Humphrey of Minnesota.

With this assurance of support, we can optimistically assume that the Public Health Service will have sufficient skilled personnel and funds to preclude the need for the simple expedient of taking a stand on mandatory secondary treatment. Instead, an intelligent case-by-case program of action will be taken to prevent or abate pollution in every problem basin in the Nation.